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Agricultural Biodiversity as a Livelihood Strategy?

The Case of Wastewater-Irrigated Vegetable Cultivation along the Musi River in Periurban Hyderabad, India

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Abstract

Agricultural biodiversity ensures the nutritional basis upon which humankind depends and therefore plays an important role in ecological and socioeconomic contexts. The rates of loss however are alarming. For this case study, diversity in vegetable varieties in wastewater and groundwater-irrigated gardens along the Musi River was mapped and compared. Interviews with local farmers were conducted to better understand the decisions behind their crop choices. Most farmers interviewed used a highly intensive, short-term cropping system. Their work exposed them to pollutants like pesticides and industrial effluents. Their land tenure situation was insecure and they were faced with fluctuating prices of inputs such as seeds, pesticides and fertilizers. The perception of agricultural biodiversity among these farmers was positive, mostly for economic reasons, but also because it was seen as strengthening resilience against negative ecological impacts. Agricultural biodiversity was thus part of the livelihood strategy as it helped to mitigate vulnerability. However, it should be assured that industrial effluences are separated from the domestic effluent which can be profitable for urban and periurban farming. Cultivating a high diversity of crops in a sustainable way requires specialised knowledge. Therefore, meaningful ways of assisting the periurban farmers would be field schools and support through agricultural extension services.

Zusammenfassung

Agrobiodiversität als eine Lebensgrundlage des Menschen spielt eine wichtige Rolle sowohl aus ökologischen als auch soziökonomischen Gründen und verringert sich gleichzeitig dramatisch. Für diese Fallstudie wurde die Diversität in abwasser- und grundwasserbewässerten Gemüsefeldern entlang des Flusses Musi nahe der indischen Stadt Hyderabad kartiert und verglichen. Die Produzenten wurden hinsichtlich ihrer Entscheidungen, die die Anbausysteme beeinflussen, befragt. Die meisten Befragten hatten ein intensives Anbausystem mit kurzen Zeitabständen zwischen Aussaat und Ernte und befanden sich in unsicheren Landbesitzverhältnissen. Sie waren sowohl Pestiziden und industriellen Abwässern als auch schwankenden Preisen für Samen, Pestizide und Düngemittel ausgesetzt. Agrobiodiversität wurde von den meisten Befragten positiv wahrgenommen, vor allem aus wirtschaftlichen Gründen, aber auch aufgrund ihres Beitrags zur Stärkung gegen ökologische Risikofaktoren. Agrobiodiversität war Teil ihrer Livelihood-Strategien und trug zur Verwundbarkeitsminderung bei. Jedoch sollten zukünftig industrielle Abwässer von Haushaltsabwässern getrennt werden, die für städtische Landwirtschaft profitabel sein können. Eine hohe Diversität an Nahrungspflanzen nachhaltig anzubauen erfordert viel Wissen. Hilfreich für Kleinbauern wären daher angewandte Wissensvermittlung und Weiterbildungsangebote und Unterstützung durch Regierungsprogramme (sog. Agricultural Extension Services).

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List of Abbreviations

AVRDC: The World Vegetable Centre

CBD: Convention on Biological Diversity

CGIAR: Consultative Group on International Agricultural Research

COP: Conference of the Parties on the Convention on Biological Diversity

DFID: Department for International Development, UK

GTZ: Agency for Technical Cooperation, Germany

IDRC: International Development Research Centre, Canada

INR: Indian Rupees (also abbreviated as *Rs* by other authors)

FAO: Food and Agriculture Organisation of the United Nations

MDG: Millennium Development Goal of the United Nations

NGO: Non-Governmental Organisation

SLA: The Sustainable Livelihoods Framework

TAK: Traditional agricultural knowledge

UNCTAD: United Nations Conference on Trade and Development

UNEP: United Nations Environment Programme

UPA: Urban and periurban agriculture

WHO: World Health Organisation of the United Nations

Dhanyavaddam

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1 Introduction

1.1 Geographical Context and Introduction to the Topic

Andhra Pradesh in South India is India's fifth-largest state. Situated in the south of the country, it has a population of 76.2 million and an area of 275,000 km² (Directorate of Economics and Statistics, Government of Andhra Pradesh, census 2001). Its capital, Hyderabad, is at 536 meters above sea level on the Deccan Plateau. Being ranked 36th in the world's largest urban areas in 2006, Hyderabad has an estimated population of 7 million (City Mayors Statistics, 2009); with a current growth rate of 27% per decade[1], Hyderabad's population is expected to reach an estimated 10.5 million by 2015. Thus, day by day the city's population increases by 500 to 1000 people. In 2007, the city absorbed ten surrounding municipalities (AMERASINGHE et al. 2008, p. 34). Located in the semi-arid tropics it receives most of the average annual precipitation of around 790 mm in the Monsoon season (June to October). The rest of the year is rather dry and the city faces increasing water scarcity since most of the ancient system of rainwater-storing lakes in and around the city has been lost to construction in the past few decades.

Figure 1: Map of India. Source: CIA

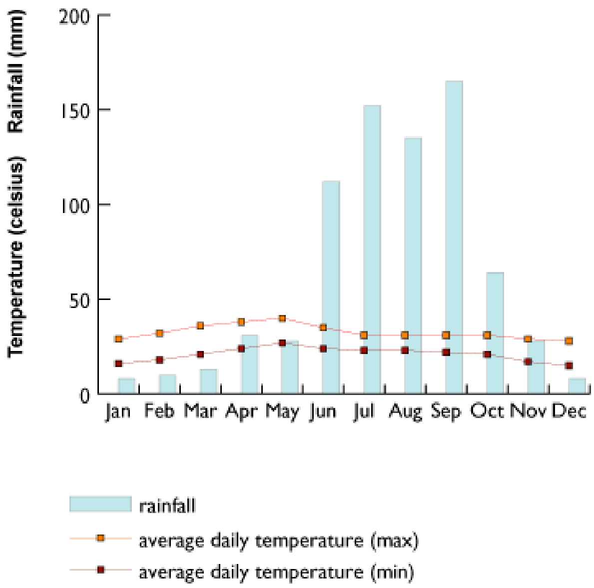

Figure 2: Climate graph Hyderabad, India. Source: BBC

In the periurban area of Hyderabad, leafy vegetables are increasingly grown along the Musi River and sold in urban markets (KRISHNAGOPAL & SIMMONS 2007). Wide areas are irrigated

[1] This and the following information is from the website of the research project "Sustainable Hyderabad – Megacities of tomorrow" at www.sustainable-hyderabad.in

with Musi River water, distributed via small canals. This water is highly polluted by more than 1,000 million litres of sewage and industrial wastewater per day discharged from the city of Hyderabad[2]. A study by BUECHLER & DEVI (2002, pp. 14-17) on wastewater irrigation and crops along the Musi River showed that periurban agriculture plays an important role for the livelihoods of a diverse group of people from different castes and religions and through a wide spectrum of social classes. One finding was that households that produce vegetables can save 20% of their total food expenditure by retaining part of the produce for household consumption (BUECHLER et al. 2006, p. 250). These types of agriculture and traditional livelihoods are subject to transition, influenced by the constant growth of the city and concomitant effects such as increasing pollution, growth of urban poverty, food insecurity and malnutrition, but may also benefit from the growing demand for food.

1.2 Leading Questions and Objectives of the Study

During an internship in the research project *Ensuring Health and Food Safety from Rapidly Expanding Wastewater Irrigation in South Asia*[3], a small survey was undertaken by the author in September 2007[4] investigating vegetables cultivated with Musi River wastewater. In order to estimate the risks from pathogens, the percentage of vegetables consumed raw was calculated. A large number of vegetable varieties appeared to flourish in the vegetable gardens irrigated with wastewater, contrary to the suggestions of various authors (see below). Even though paragrass (*Urochloa mutica*), a fodder crop, and rice (*Oryza sp.*) were the dominant crops in the periurban fringes, the vegetable gardens played an important role by providing leafy vegetables and supporting livelihoods of smallholder farmers, many of whom were women (BUECHLER & DEVI 2002). On one third of the area under cultivation spinach (*Spinacea oleracea*) was grown. Other important crops included amaranth (*Amaranthus tricolor,* 15.7%) and roselle (*Hibiscus acetosella var. sabdariffa*, 12.4%). These leafy vegetables are traditionally in high demand, have a short growth phase and fetch high market prices due to their role in traditional dishes. Many of the varieties (27 out of 53) are mentioned in the "*List of Underutilized Species and Countries*"[5] by the *Global Facilitation Unit*

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[2] Information from IWMI, based on the Hyderabad Metropolitan Water Supply & Sewerage Board (HMWSSB), 2008

[3] In cooperation with the *Section on Applied Geography of the Tropics and Subtropics* (APT), University of Freiburg, Germany, duration: 2005-2008, coordinated by the International Water Management Institute (IWMI), funded by the German Ministry of Economic Cooperation and Development (BMZ). In the following, this project will be referred to as the IWMI project.

[4] Results presented as a poster at the North South Centre (annual conference), ETH Zürich, 4. 6. 2008.

[5] The complete list can be found on the GFU website

for Underutilized Species (GFU). Thus, further research on these vegetables and their role for food security can be considered important. With regard to agricultural biodiversity, the *International Food Policy Research Institute* (IFPRI) stated in 1993:

> *"Agricultural research directed toward diversification in crop production including fruits and vegetables, livestock, fishery, and agriculture should be encouraged. A diversified cropping strategy may help eliminate much of the seasonality in production and consumption as well as the concomitant negative effects on nutrition"* (KENNEDY & BOUIS1993, p. 19).

It is widely accepted that agricultural biodiversity contributes directly to sustainable livelihoods *"in both traditional and industrial-type agricultural systems through production effects and important ecosystem functions"* (CROMWELL et al. 2001, p. 91; also cf. SMALE 2007). Article 12 of the *Convention on Biological Diversity* seeks to "*promote and encourage research which contributes to the conservation and sustainable use of biological diversity, particularly in developing countries*" (CBD homepage). The Food and Agriculture Organisation of the United Nations (FAO) calls for research to assess the extent and distribution of diversity and to document factors that influence farmers' decisions and crop selection processes (FAO 2007a).
Another important motivation for this study was that various authors have suggested that agricultural biodiversity decreases with the use of wastewater (CLEMETT & ENSINK 2006; ENSINK 2006, p. 33; KASPERSMA 2002; VAN DER HOEK et al. 2002, p. 11).

This leads to the following research questions:

What are the vegetable varieties cultivated and what is the extent of cultivation in the selected periurban areas of Hyderabad?

Is there a difference between the range of agricultural biodiversity in wastewater-irrigated and groundwater-irrigated gardens?

Which factors influence the farmers' decision making on what to cultivate where and in what quantity?

What is the role of agricultural biodiversity for the producers' livelihoods and what are their adaptation strategies to ecological and economic threats?

The overarching research hypothesis for this study is:

A broad diversity of vegetable varieties is cultivated in periurban Hyderabad as determined by several factors of different importance for decision making including traditional agricultural knowledge or irrigation water quality. Diversity as an adaptation strategy is important to the producers' food security and livelihoods.

In the following, the crop diversity in the vegetable gardens of the research area is described and compared. After this, the factors and interrelations that determine farmers' crop choices as well as the influence of different irrigation water types on crop diversity are examined. The first part of the study is based on mapping and the second part on farmer interviews. Literature review is used to substantiate and confirm the results. Ultimately of importance is eventually the question whether the case of Hyderabad is comparable to other regions of the world where vegetables are cultivated in urban and periurban areas often with wastewater irrigation and what the risks, benefits, perspectives and potentials are. The overall objective is to analyse the species composition owing to wastewater irrigation, the role of crop diversity in the livelihoods context of vegetable producers in the case of periurban Hyderabad and, eventually, to contribute to research with the aim of improving food security.

2 Background: Agricultural Biodiversity in the Global Context

In the next five subsections, the main topics addressed in this study are put into a global context. After this, the focus narrows down to the case study on the outskirts of Hyderabad.

2.1 Food Insecurity and Urbanisation in India

In spite of the Green Revolution having quadrupled the total food grain production of India from 50 million tons in 1950/51 to over 200 million tons in the year 2000/01 (BAMJI 2005; cf. ALTIERI et al. 1998), more than 20% of the Indian population are still undernourished (FAOSTAT homepage) and over 38% of children under three years are underfed in Indian cities (GRAGNOLATI et al. 2005, p. 11). India is the nation with the largest number of hungry persons worldwide (212 million, FAO 2006).

The *Food Insecurity Atlas of Urban India* looks at the term *Food Insecurity* from three different viewpoints (MURALI 2002, pp. 1-3):

- the availability of food depending on production and distribution,
- access to food determined by purchasing power of individuals,
- The general conditions under which a sufficient supply of food can contribute to a healthy and long life (sanitation, clean drinking water and primary health care are crucial to maintain this point).

This shows that the problem is severe but also complex and an exclusive focus on undernutrition statistics is not sufficient for "*eradicating world hunger"* (FAO 2006, Title*)*. Whereas the term *hunger* is rather quantitative, *malnutrition* implies undernutrition as well as emerging obesity with implicated health problems. Statistics indicate that by 2030[6] diabetes in India will rise to 6.9% of the population. In Hyderabad, around 17% of the population suffer from the disease[7], which is mainly caused by obesity according to the World Health Organisation (WHO 2003a, pp. 72-77).

Particularly in developing countries, rapid urbanisation processes occur that challenge the future of humankind. The world's urban population is increasing steadily: UN-HABITAT (2008) states in the *State of the World Cities 2008/9* report that more than half of humanity currently lives in cities and by 2050, 70% will be urban dwellers. Urbanisation in India is proceeding rapidly, although the grade of urbanisation in India is rather low with around 30% of the population (more than 50% of which live in slums or under slum-like conditions, UN-HABITAT 2007, p. 352). Whereas small urban centres are shrinking, it is estimated that 55% of the Indian population will live in urban areas by 2050 mostly in mega cities (ibid.). Persons migrating to cities in great numbers in search of work and a better livelihood are often unsuccessful in finding either. It is estimated that of the one billion persons that live in slums worldwide, more than half of this number are in Asia. With the rapid urbanisation come certain challenges like rising food prices and in water scarce areas insufficient access to water. Urban dwellers whom have to purchase most of their food are more dependent on food and water prices than people living in rural areas. They are also more prone to diseases related to poor water quality and pollution (IDRC 2005, p. 7).

Before the Indian economist and Nobel price laureate Amartya Sen published "*Poverty and Famines*" in 1981, hunger and malnutrition were (and still are by many researchers and organisations[8]) regarded as a problem of not producing enough food (ALTIERI & ROSSET 1999; ALTIERI 2002, p. 5). Amartya Sen showed that often, entitlements, i. e. the possibility to purchase and to produce food, are the real root cause of undernutrition and starvation (cf. SEN 1999; CHAMBERS & CONWAY 1992). ALTIERI & ROSSET (1999, p. 1) stated:

> "*There is no relationship between the prevalence of hunger in a given country and its population (…) the world today produces more food per inhabitant than ever before. Enough food is available to provide 4.3 pounds for every person everyday: 2.5 pounds of grain, beans and nuts, about a pound of meat, milk and*

[6] WHO Statistics on diabetes can be accessed at http://www.who.int/diabetes/facts/en/diabcare0504.pdf.

[7] The Website „Medindia" titles: "*Hyderabad is the Diabetes Captial of India*" (see References)

[8] Compare statements by the CGIAR such as: "priorities of CGIAR research are (…) reducing hunger and malnutrition by producing more and better food through genetic improvement", see CGIAR homepage

eggs and another of fruits and vegetables. The real causes of hunger are poverty, inequality and lack of access to food and land. Too many people are too poor to buy the food that is available (but often poorly distributed) or lack the land and resources to grow it themselves".

The United Nations *Millennium Development Goals* (MDGs) aim "*to eradicate extreme poverty and hunger"* by halving the proportion of persons suffering from hunger and poverty[9]. The World Food Summit 2002[10] reaffirmed the right of everyone to have access to safe, nutritious, and culturally relevant food. However, the progress towards these aims is uneven (compare the *mdgmonitor*[11]).

Homegardens or allotment gardens are believed to be a viable option to increase household income and food supply in urban agglomerations including a diversified diet and sufficient intake of vitamins. Recommendations are to promote urban green belts and urban agriculture, not only to create livelihoods and produce more and better food but also to improve the urban environment and quality of life as parks and gardens can be considered as green lungs of urban agglomerations (DRESCHER et al. 2006; FAO 2007b; YASMEEN 2001, pp. 27-28).

2.2 The Role of Urban and Periurban Agriculture

Urban poverty as mentioned above, is contrary to rural poverty characterized by a greater dependence on cash, because all essentials of daily life must be purchased (IDRC 2005, p. 7). The current food crisis affects the urban poor population in particular: Whereas in Europe, the average expenditures for food from the household income are around 10-15%, in some developing countries they reach more than 60% (FAO 2008a, p. 27). Urban and periurban agriculture (UPA) can be a way of meeting some of these challenges: Research outcomes from the last years show that e. g. in Dhaka, Bangladesh, 80% of households keep livestock. In Lusaka, Zambia, 45% of families are involved in urban or periurban agriculture and 80% in Libreville, Gabon. In Accra, Ghana, 80% of the consumed vegetables are produced within the city boundaries (MILLSTONE & LANG 2008, pp. 54-55).

Nevertheless, urbanisation processes and rural development are interlinked activities and planning or development policies often influence both, especially in periurban areas (IAQUINTA & DRESCHER 2000). One of the key characteristics of periurban areas is that they

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[9]More information on the Millennium Development Goals available at the MDG homepage

[10] World Food Summit "five years later", 2002, report available at the FAO homepage

[11] The progress can be followed at the *Millenium Development Goals Monitor* homepage

are dynamic, which makes it difficult to distinguish the periurban area from urban and rural areas. This difficulty is reflected in the OECD definition of the term *periurban* in 1979 which has been widely used:

> *"The term 'periurban area', cannot be easily defined or delimited through unambiguous criteria. It is a name given to the grey area which is neither entirely urban nor purely rural in the traditional sense; it is at most the partly urbanized rural area. Whatever definition may be given to it, it cannot eliminate some degree of arbitrariness"* (OECD 1997, cited in: Ibid., p. 2).

Important for the characterisation of a periurban area are a few components identified by IAQUINTA & DRESCHER (2000, p. 3): Whereas the overall character is rather rural, the periurban area is influenced by urbanisation processes with ecological, economic and social aspects. The term periurban has a demographic, a geographic as well as a temporal component considering the dynamics of a periurban area. Figure 3 shows the different phases in the development from rural to urban taking into account administrative and institutional components under the premise of migration.

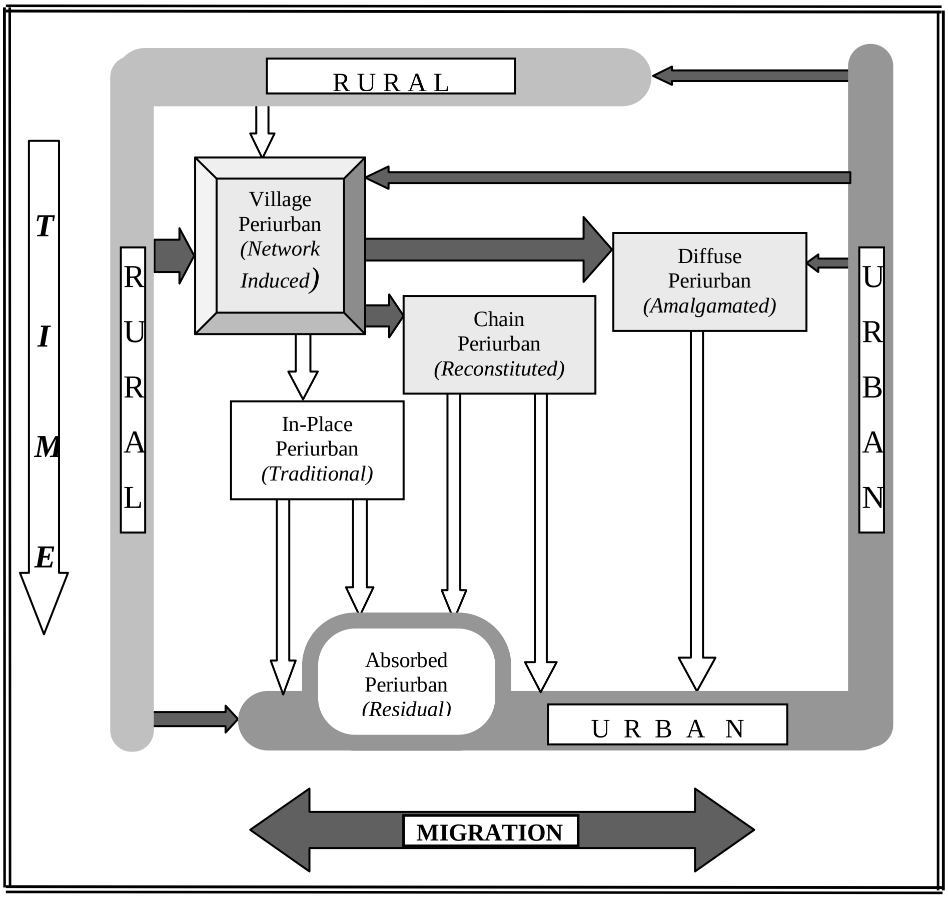

Figure 3: Periurban synthesis (typology) with institutional contexts. Source: IAQUINTA & DRESCHER 2000, p. 11

Two major movements can be observed in the periurban fringes of Hyderabad selected for this study: On the one hand the in-migration of people moving to the city in search of work and, in the case of the farmers, in search of a reliable water source. On the other hand the expanding city with new apartments and office buildings, schools and industries et cetera overrunning the agricultural areas and water bodies (cf. IWMI/RUAF 2007, p. 12).

Agriculture in urban agglomerations *"integrates a variety of physical, social, and economic functions"* (DRESCHER et al. 2006, p. 320). It supplies the opportunity not only to produce food and cultivate medical plants for the market as well as for self-consumption, but also to reuse resources such as waste and water. Agricultural areas can fulfil social functions like the creation of playgrounds for children. Moreover (and of particular importance for this observation), *"homegardens play an important role in the conservation of indigenous crops, thus enhancing biodiversity in rural, periurban and urban environments"* (ibid.).

The *International Development Research Centre* Canada (IDRC) gives the definition of UPA as follows*:*

> *"Urban and Periurban agriculture or UPA is an industry located within or on the fringe of a town, a city or a metropolis, which grows or raises, processes and distributes, diversity of food and non food products, (re) using largely human and material resources, products and services found in and around the urban areas*" (cited in: KRISHNAGOPAL & SIMMONS 2007, p. 5).

UPA in Hyderabad contributes to the city's food supply mainly through the cultivation of fodder grass for dairy farms and, increasingly, through vegetable cultivation (ibid.). It was stated that "*there is tremendous opportunity for locally produced (either at a commercial or household scale) perishable vegetables to meet the increasing market demand and to act as a buffer to escalating food prices"* (IWMI/RUAF 2007, p. 24). From 75 to 80% of the vegetable demand of Hyderabad is produced in urban or periurban areas in four major production belts from October to January; during the rest of the year, only 30% of the urban demand is met. For the period of this time, the vegetables are supplied from the areas *Ibrahimpatnam* to *Chowtuppal, Vijaywada-Mangalgiri* and *Bangalore-Kolar* (KRISHNAGOPAL & SIMMONS 2007, p. 14). A landuse classification (Figure 4) by the *Hyderabad Urban Development* Agency (HUDA) indicates that even in rural Hyderabad, around 66% of the total land area were vacant or used for agriculture in 2002 (approximately half of this share was agricultural land, IWMI/RUAF 2007, p. 13).

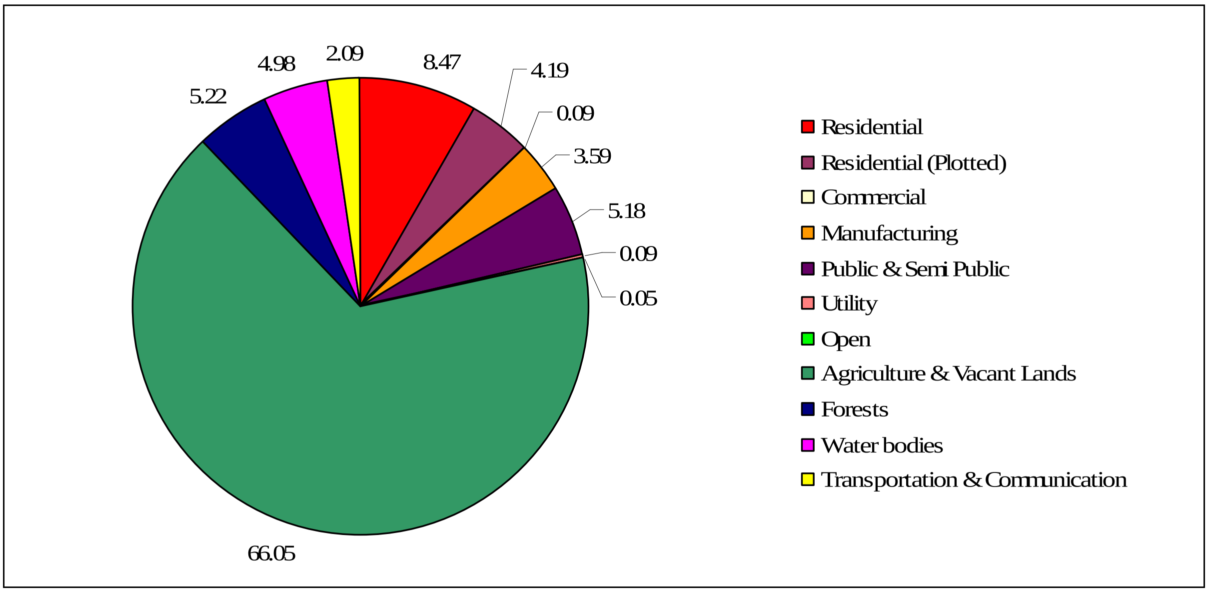

Figure 4: Landuse classification for Hyderabad, 2000. Source: IWMI/RUAF 2007, p. 13

However, UPA in and around Hyderabad is difficult; concerning food and nutritional security in Hyderabad, IWMI/RUAF (2007, p. 21) stated that high land prices under the pressure of urbanisation have led to "*escalating vegetable prices in Hyderabad*". Moreover, it becomes more and more difficult to find seasonal workers since construction absorbs labour "*due to higher wages and consistent employment*". Furthermore, there are the assumed health risks from the use of wastewater for irrigation (cf. Chapter 2.5).

2.3 Vegetables in the Global Food Security Discussion

In view of malnutrition, leading to obesity as well as to starvation, researchers and organisations search for ways to ensure a sustainable food production and worldwide food security. Vegetables are believed to contribute significantly to a healthy and balanced diet, providing all essential nutrients. According to the WHO, 2.7 million deaths per year are caused by insufficient fruit and vegetable consumption, which is one of the "*top 10 selected risk factors for global mortality*" (WHO 2002). 19% of gastrointestinal cancer, around 31% of ischaemic heart disease and 11% of stroke are caused by the low intake of fruit and vegetables (ibid.). Vegetables are particularly important for the poorest in urban agglomerations, as their food diversification is usually much lower than in rural areas (BOZZINI 2004, p. 101).

The Joint FAO/WHO *Expert Consultation on diet, nutrition and the prevention of chronic diseases* (2003) recommends a daily intake of at least 400 grams per person of fruit and vegetables (average consumption in India: 120-140 grams, WHO 2003a, p. 23) for a healthy life and sees a "*substantial potential for preventing cancer through diet, particularly through the consumption of fruit and vegetables*" (ibid., p. 8). At the same time, it is claimed that *“every person has the right to safe and nutritious food”*[12]. Over two billion persons are estimated to suffer from micronutrient deficiencies worldwide (e. g. vitamin A, cf. Table 1) that could be mitigated by consuming vegetables (FAO 2007a).

Table 1: Prevalence of micronutrient deficiencies (women and children) in South Asia. Source: GRAGNOLATI et al. 2005, p. 5

	Iron deficiency				Vitamin A deficiency			Iodine deficiency			Folate deficiency
	IDA in children <5y (%)	IDA in women 15-49y (%)	IDA in pregnant women (%)	Maternal death from severe anemia/yr (no.)	Child deaths precipitated (no.)	Children <6 w/ subclinical VAD (%)	Children <6 w/ clinical VAD (%)	Children born mentally impaired (no.)	Total Goiter Rate (TGR) (%)	Total Goiter Rate (TGR) in school children (%)	Neural tube defects (no.)
Afghanistan	65	61	-	-	50,000	53	-	535,000	48	-	2,250
Bangladesh	55	36	74	2,800	28,000	28	0.7	750,000	18	50	8,400
Bhutan	81	55	68	<100	600	32	0.7	-	-	14	150
India	**75**	**51**	**87**	**22,000**	**330,000**	**57**	**0.7**	**6,600,000**	**26**	**19**	**50,000**
Nepal	65	62	63	760	6,900	33	1.0	200,000	24	40	1,600
Pakistan	56	59	-	-	56,000	35	-	2,100,000	38	-	11,000
South Asia Region Total				25,560	471,500			10,185,000			73,400
World Total				50,000	1,150,000			19,000,000			204,000

The *German Society for Technical Cooperation* (GTZ) even argues that the consumption of vegetables is a viable option to alleviate after-effects resulting from HIV/AIDS (GTZ 2007). Therefore, the *WHO Fruit and Vegetable Promotion Initiative* launched in 2003 seeks to empower fruit and vegetable producers, both commercial and subsistence farmers and raise awareness on the issue at all imaginable stakeholder levels with numerous partners[13] (cf. WHO 2003b, p. 19). This makes sense since the worldwide supply of vegetables has been rising constantly since the 1980s as indicated in Figure 5, but the average daily consumption is still below official recommendations.

[12] As stated at the World Food Summit 1996, Rome

[13] E. g. “European Partnership for Fruits Vegetables and Better Health” or “International Fruit and Vegetables Alliance”

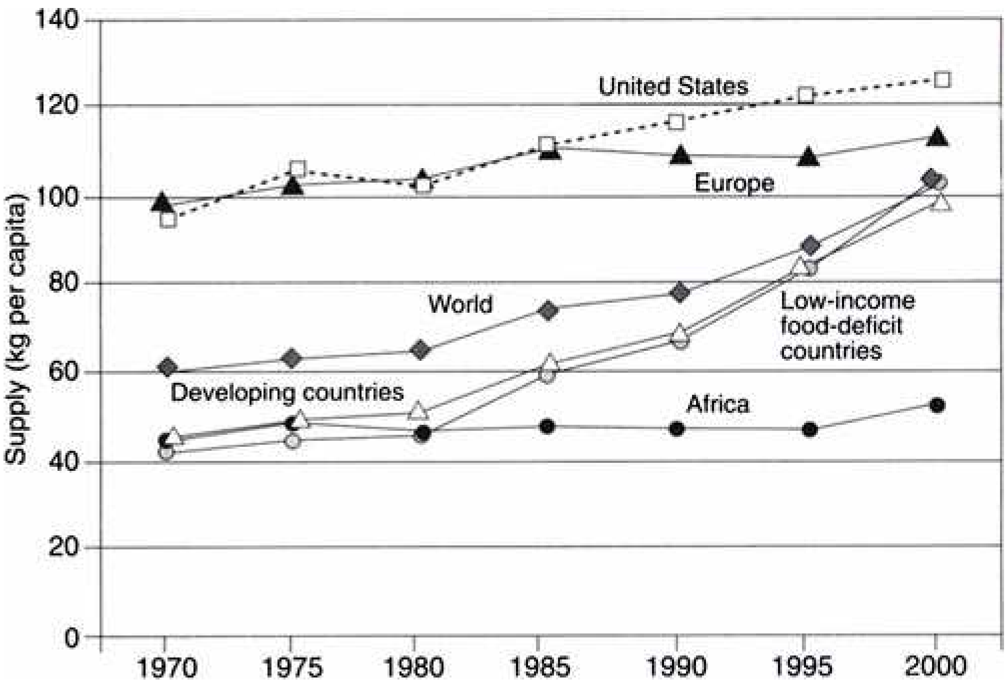

Figure 5: Trends in the supply of vegetables per capita, per region. Source: WHO 2003a, p. 25

There are innumerable definitions for the term *vegetable* varying between countries and regions (cf. WHO 2003b, p.13). A rather broad definition from the FAO refers to *The Shorter Oxford Dictionary* (1973):

> *"A vegetable is a plant cultivated for food, especially an edible herb or root used for human consumption. In general, vegetables tend to be less sweet than fruits and often require some form of processing to increase their edibility."* (FAO website)

It is difficult to classify food crops into vegetables or non-vegetables following this definition and therefore it is more viable to find a definition according to the respective cultural context. Definitions can be based on botany (which would e. g. classify tomatoes, cucumbers and pumpkins as berries), on the use and taste (processed or raw, sweet or salty…) or even on their contents:

> "*Many definitions specify that vegetables are parts of a plant, are eaten cooked or raw with main meals, have different colours, are high in nutritional value and are good for health. Differences in definitions occur with respect to the inclusion or exclusion of starchy tubers, beans, lentils and corn. Definitions of fruit were found to be more consistent across countries and regions than the definitions of vegetables*" (WHO 2003b, pp. 5-6).

In the "*World Programme for the Census of Agriculture 2010",* the FAO subdivides nine classes of crops. The class *Vegetables and Melons* contains leafy or stem vegetables, fruit bearing vegetables, root, bulb or tuberous vegetables as well as mushrooms. *Root/tuber crops with high starch or inulin content* (e. g. sweet potato) are an additional class but added in this observation as well as spice and leguminous crops which form two more classes (FAO 2005, pp 144-147). For this study, the farmers' perception was helpful to define vegetables: Flowers, fruit trees and cereals were left out, legumes and groundnuts were considered as vegetables (*Oilseed* in the FAO classification).

2.4 The Importance of Agricultural Biodiversity

Agricultural biodiversity (also agrobiodiversity or crop diversity) is the biological basis of agriculture. For centuries, farmers all over the world have been rearing high-yielding varieties, well adapted to the particular habitat and climate. The *Conference of the Parties to the Convention of Biological Diversity* (*COP*) defined the term in 2000:

> *"Agricultural biodiversity (…) includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: The variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes."*[14]

The Convention on Biological Diversity, also known as Rio Convention, was ratified in 1992 by 191 nations (excluding the USA) with three main aims: To sustain biodiversity, maintain a sustainable use of its components and guarantee the fair and equitable sharing of benefits arising from genetic resources. The parties strive for an ambitious goal:

> *"The Parties to the Convention committed themselves to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth. This target (…) was incorporated as a new target under the Millennium Development Goals."*[15]

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[14] COP decision V/5, 2000, see COP website

[15] 2010 Biodiversity Target: CBD website, in MDG no. 7: "Ensure Environmental Sustainability".

The *Green Revolution* in the 1960s and 70s has been criticized for destroying traditional knowledge and sustainable farming systems by introducing *improved varieties* and promoting the use of chemical fertilizer and pesticides (ALTIERI & ROSSET 1999; SHIVA & PANDEY 2006; FRESCO & BAUDOIN 2004, p.29). The FAO estimates that 75% of all agricultural plants have been lost during the last 150 years (cited in: GTZ 2004, p. 20), and that the world's population depends on only approximately 150 food crops today. 90% of the world's food energy requirements are met by only 15 food plants and 8 animals (FAO 2007a). The development towards monocultures is widely linked to a deepening divide between rich and poor farmers and to a loss of agrobiodiversity which forms the basis of livelihood security (cf. KOTHARI 1997, p. 53; ALTIERI 2002). In Bangladesh, the promotion of improved rice varieties in the course of the *Green Revolution* resulted in the loss of nearly 7,000 traditional rice varieties and a movement towards monocultures (THRUPP 2003, p. 322). Thus, the Green Revolution has been associated with ecological deterioration, poorer diets with nutritional losses and the economic decline of smallholders (GRENIER 1998, p. 86). Increasing reliance on a narrow range of crops represents a high-risk proposition and causes severe threats for global food security (KOTHARI 1997, p. 56), as witnessed in the *Great Irish Famine* in the mid 19th century when people relied on one potato variety which was infected by a fungus[16]. Moreover, loss of genetic diversity is associated with an increasing dependence of the farmers on the industry-dominated market and government (ibid.). The Indian activist *Vandana Shiva* even links farmer suicides to the dispersion of industrial cash crops, e. g. *Bollgard*® cotton (genetic modified cotton producing a toxin from a gene taken from *Bacillus thuringiensis*) by the company *Monsanto* (SHIVA 2000, p. 142).

Agricultural Biodiversity is thus threatened by several factors such as genetic uniformity in spreading monoculture, climate change, increased risks through newly introduced pests or pathogens, to name only a few factors (as listed by the Crop Diversity Trust[17]). Also the destruction or conversion of habitats to which agricultural varieties were especially adapted and the disruption of traditional lifestyles have caused erosion in agricultural biodiversity (KOTHARI 1997, p. 54). In recent years, there has been a growing interest both from governmental and non-governmental organisations in agrobiodiversity, its conservation and the propagation of species and knowledge. Genetic diversity is frequently correlated with food security and there have been numerous calls for the protection and promotion of agricultural biodiversity (cf. IPGRI/Bioversity International homepage). The *International*

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[16] Also other reasons are discussed concerning the *Great Irish Famine*. More information for instance at: http://mises.org/story/2978 "What caused the Irish potato famine?"

[17] "*The Global Crop Diversity Trust was founded by the United Nations Food and Agriculture Organisation (FAO) and Bioversity International, acting on behalf of the foremost international research organizations in this field (CGIAR). The Trust is currently hosted in Rome by FAO*." Self-portrayal from: http://www.croptrust.org, Threats: http://www.croptrust.org/main/threats.php?itemid=23

Treaty for Plant Genetic Resources for Food and Agriculture[18] for instance has the task to unify the nations in the aim of collecting and conserving all existing agricultural varieties. The system of *Access and Benefit-Sharing* implemented by the COP/CBD is meant to ensure, that plant resources including the associated knowledge are available and accessible (ESQUINEZ-ALCAZAR 2005). The UNESCO even claimed that *"Maintaining a diversity of crops and varieties is a key to survival of millions of farmers living on impoverished land"*[19]. Thus, the issue is important for several reasons and for stakeholders on all levels:

> "*Conservation of crop diversity matters to the public, researchers, and policy-makers as concern grows over the loss of biological diversity (…) and the loss of local ethnobotanical knowledge because it represents the irreversible loss of humanity's heritage and diversity"* (REYES-GARCIA et al. 2008, p. 3).

Numerous organisations working on the issue have come into existence such as the *International Centre for Underutilized Crops* (ICUC), and the *Global Facilitation Unit for Underutilized Crops and Species* (GFU). Further, the Consultative Group on International Agricultural Research (CGIAR) *"has put considerable effort into creating a network of centres whose primary goal is to provide ex-situ conservation for crop diversity"* (ibid.). Already at the FAO *World Food Summit* 1996, the facilitation of indigenous, habitat adapted species was postulated and knowledge gaps concerning agricultural biodiversity were highlighted.
To summarise, genetic diversity rather than species diversity is the important aspect of biodiversity for agriculture and food security. The ongoing decline of biodiversity erodes the genetic base on which humankind relies (KOTHARI 1997).

2.5 The Use of Wastewater in Irrigated Agriculture

The often already insufficiently developed urban infrastructures particularly in developing countries are under pressure from rapid urbanisation processes. Everyday, great volumes of wastewater are produced and often released into the next water body. In Hyderabad alone, around 1,200 million litres of wastewater per day are generated[20]. Since the city is located in an area of physical water scarcity, the urban water supply is currently met by diverting water

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[18] More information at: http://www.planttreaty.org/

[19] Statement from the UNESCO Homepage: Genetic Diversity and Food Security: http://www.unesco.org/courier/2000_05/uk/doss23.htm

[20] Calculated in 2006 for the research project *Ensuring Health and Food Safety from Rapidly Expanding Wastewater Irrigation in South Asia* by IWMI India, cf. Introduction

from sources outside the catchment area and pumped over distances of several hundred km (VAN ROOIJEN et al. 2005, p. 82). Around 80% of the water leaves the city as wastewater. Currently, more than 70% of wastewater is untreated in India (SCOTT et al. 2004, pp. 3 and 28).

RASCHID-SALLY & JAYACODY (2008, p. 5) define *urban wastewater* as "*a combination of one or more of the following":*

*-Domestic effluent consisting of **black water** (excreta, urine, and associated sludge) and **grey water** (kitchen and bathroom wastewater)*
-Water from commercial establishments and institutions, including hospitals
*-**industrial** effluent*
*-**storm water** and other urban run-off."*

In the context of the abovementioned challenges, many farmers in developing countries use urban wastewater for irrigation. Reliable information on the global extent of wastewater-irrigated agriculture is missing; estimates range from 3.5 to 20 million hectares (SCOTT et al. 2004, p. 6). With its high content of nutrients, wastewater is often used for very intensive agriculture. In Hyderabad, according to RASCHID-SALLY & JAYACODY (2008, p. 5), the situation can be specified as an

> "*indirect use of untreated or partly treated urban wastewater: when water from a (polluted) river receiving urban wastewater is abstracted by many users at many points downstream of the urban centre for agriculture. This happens when cities do not have an operational sewage collection network and drainage systems collecting wastewater discharge into rivers."*

Figure 6: Wastewater disposal, image by P. Weckenbrock

Figure 7: Weir with foam at the Musi River, image by L. Suchenwirth

The *WHO Guidelines for the safe Use of Wastewater, Excreta and Greywater* quote that "*More than 10% of the world's population consumes food produced with wastewater. The percentage will be considerably higher among populations in low-income countries in arid and semi-arid climates"* (WHO 2006, p. 6). There are numerous risks associated with the use of wastewater in agriculture such as the outbreak of diseases namely cholera, typhoid and dysentery. According to the WHO, helminth infections pose the most important health risk followed by bacterial and viral diseases (ibid., pp. 9 and 20). Potential risks for producers, consumers, environment and population in wastewater-irrigated areas are displayed below.

Hazards and exposure routes associated with the use of wastewater (WHO 2006, p. 20):

Excreta-related pathogens:
***Bacteria** (Escherichia coli, Vibrio cholerae, Salmonella spp., Shigella spp.)* ***Helminths**: Soil-transmitted helminths (Ascaris, Ancylostoma, Necator, Hymenolepis, Strongyloides, Toxocara, Trichuris, Taenia spp.),* ***Trematodes** (Clonorchis, Opisthorchis, Fasciola, Schistosoma spp.) Protozoa (Giardia, Cyclospora, Cryptosporidium, Entamoeba spp.)*

***Viruses** (hepatitis A and E viruses, adenovirus, rotavirus, norovirus)*

***Vector-borne pathogens** (Plasmodium spp., dengue virus, Wuchereria bancrofti, Japanese encephalitis virus)*

Skin irritants

Chemicals:
Antibiotics (chloramphenicol), cyanobacterial toxins (microcystin-LR), heavy metals (arsenic, cadmium, lead, mercury), phthalates and phenols, halogenated hydrocarbons (dioxins, furans, PCBs), pesticides and their residues (e.g. aldrin, DDT)

Figure 8: Hookworm larvae. Source: US Department of Health and Human Services

Table 2: Distribution of crop types cultivated with wastewater. Source: RASCHID-SALLY & JAYACODY 2008, p. 22

Type of crop	Number of cities*			
	Africa	Asia	Latin America	Middle-East
Vegetables	8	16	7	1
Cereals	5	15	5	2
Fodder	1	5	3	0
Other	1	5	3	2

*multiple responses were possible

Table 2 shows that the proportion of food produced with wastewater has the largest share in Asia, especially in terms of vegetables. As will be addressed below, vegetable production plays an important role in the livelihood strategies of many farmers. The discussions have shifted from whether to use wastewater in agriculture or not to the question of how it can be used more safely and sustainably (SCOTT et al. 2004, cited in VAN ROOIJEN et al. 2005, p. 82).

3 Conceptual Framework, Methodology and Research Design

To combine the abovementioned factors influencing agricultural biodiversity and the socio-economic situation of vegetable producers in periurban Hyderabad requires an interdisciplinary approach. In the following, the topic is embedded in a theoretical framework. After this, the field methods and the analytical tools are described.

3.1 The Sustainable Livelihoods Approach and the Homegarden Model

"Problems that are thought to be biological or technical often have their roots in sociocultural arrangements and processes" (IAQUINTA & DRESCHER 2000, p. 8).

It is very important not to approach the rather complex situation in the case of vegetable farming in periurban Hyderabad only from one point of view but to explore interrelations. Not only the ecosystem with the natural resources but also the farmers and their decisions are important, and so are the growing city and the market demand. Thus, a multidisciplinary approach is imperative. For this study, the objective is to analyse crop diversity from an agricultural and botanical point of view as well as using an anthropological approach to analyse the farmers' decision making process (what to cultivate where and why):

> *"The interplay between wastewater users, agriculture, agroforestry, animal husbandry and aquaculture on the one hand, and soil, plant and wastewater quality on the other hand, needs to be elucidated through an integrated, holistic conceptual framework"* (BUECHLER 2004, p. 30).

A combined approach of analysing the natural systems and the social systems must be used as they are not separated in reality. It is argued that "*using a livelihoods approach for wastewater studies would centre research on the actors (...) of particular importance are decision making processes"* (ibid.), who are in the end crucial either cultivating or not cultivating a broad diversity of crops. The Sustainable Livelihoods Approach (SLA) developed by the Department for International Development (DFID, UK) is a promising method to bridge the gap between social and natural sciences. It is based on the findings of the Indian economist Amartya Sen regarding *Entitlements* and *Capabilities.* Capability means among others "*being able to perform certain basic functionings and (…) to cope with and recover from stress and shocks"* (CHAMBERS & CONWAY 1992, p. 4). *Equity* is the relative asset distribution including opportunities and enhancement. A livelihood is sustainable when it is able to maintain the assets and capabilities on which it depends (ibid., p. 5). Thus, the terms *Capabilitiy*, *Equity* and *Sustainability* are the core values of the SLA.

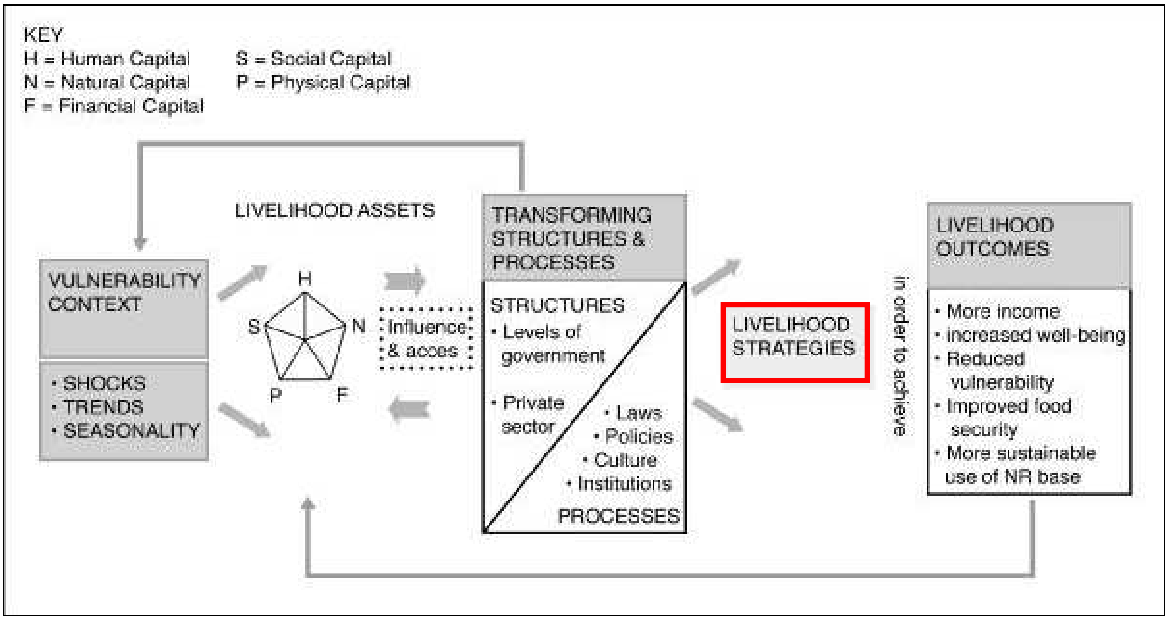

Figure 9: The *Sustainable Livelihoods Framework*. Source: DFID 2001, modified.

This study focuses on the **livelihood strategies** that are chosen to reach "*Livelihood outcomes*". There is no explicit orientation towards poverty itself in the SLA as this is difficult to measure, but to assets (instead of problems), structures, processes and reactions that influence the overall livelihood situation to reach in the end a holistic understanding of the term poverty (cf. BUECHLER 2004, p. 26). It follows that "*poverty is the lack or loss of sustainable livelihoods*" and "*the risk of livelihood failure determines the level of vulnerability of a household*" (DFID 2001, Glossary Sustainable Livelihoods). Livelihoods can be approached from different levels: The **macro level** comprises politics on the national and supranational levels whereas **meso** and **micro** level focus on the scale of a region, village, kin networks, households or individuals. Figure 10 shows the interrelations between poverty and environmental stress in urban and urbanised areas based on the livelihoods framework. The functional chain leads from discriminated entitlements over marginal and/or degraded land, environmental burdens such as polluted resources to limited assets that are crucial for sustainable livelihoods and result in vulnerability and poverty.

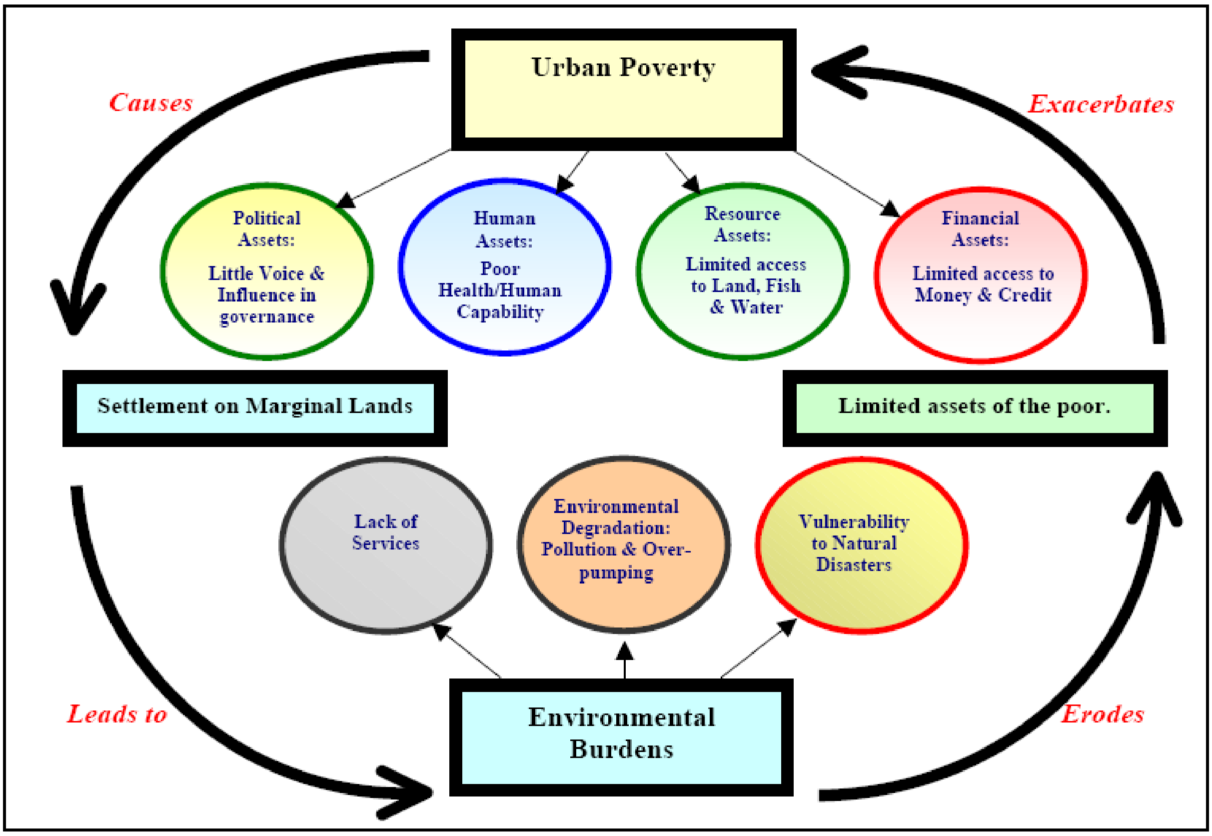

Figure 10: Urban poverty and environmental burdens. Framework by: IDRC 2005, p. 8

In order to apply the conceptual approach to the case study, a model was used for data analysis. Based on the SLA it locates gardening within the livelihood strategies of the households (DRESCHER et al. 2006, pp. 327-328). The model was developed by DRESCHER & BOS (1994) to analyse homegardens and was altered by DRESCHER (1998, p. 30) to include other garden systems, e. g. allotment gardens (DRESCHER et al. 2006, p. 327).

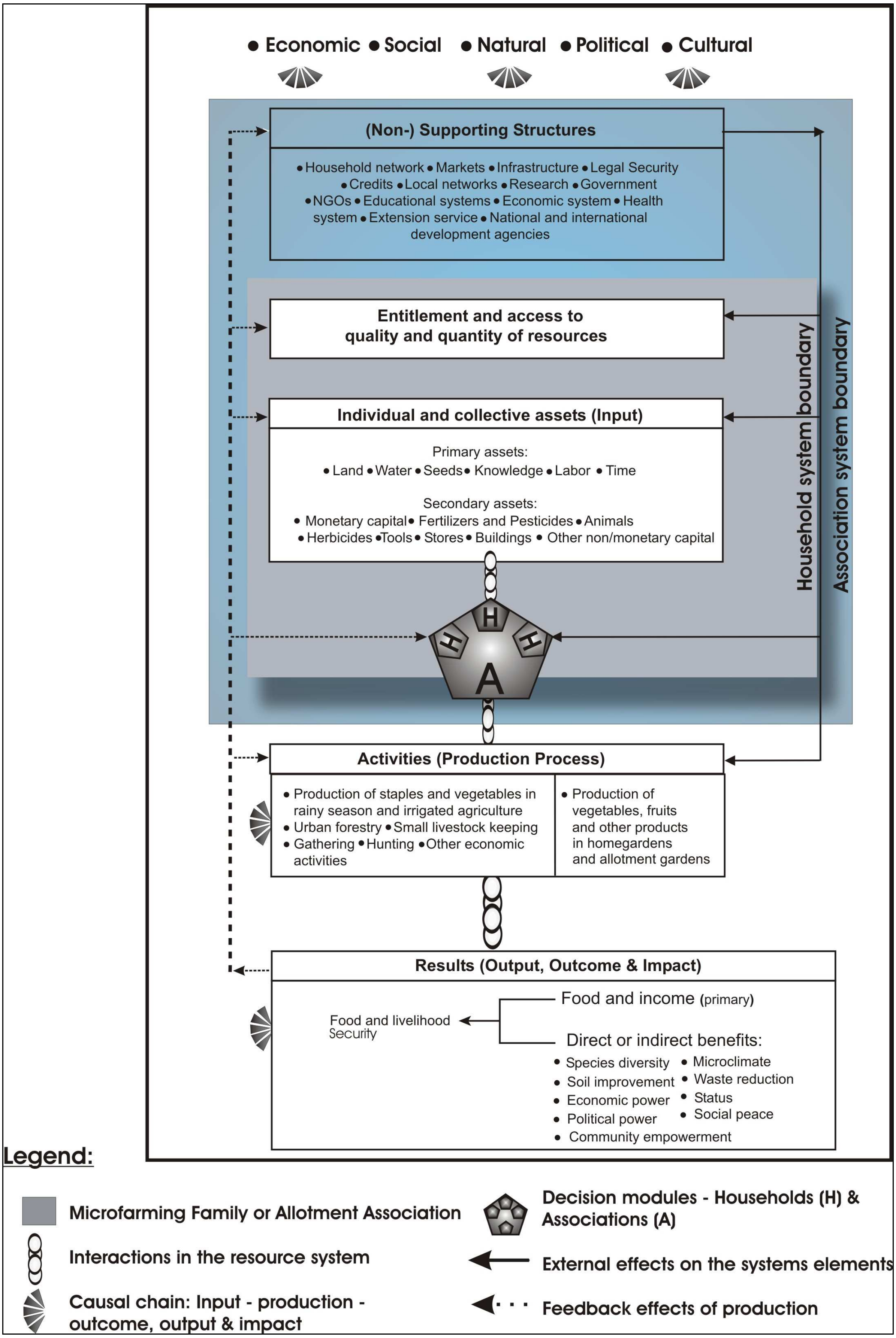

Figure 11: Conceptual framework “Homegarden Model” adapted to gardening in urban and periurban areas. Source: DRESCHER et al. 2006, p. 328

Within the model, gardening forms a contribution to the livelihood strategy. The farming groups as decision makers are represented by a pentagon in the middle, directly influenced by and influencing the assets as in the DFID's SLA. Entitlements in the sense of Amartya Sen (cf. SEN 1999), assets and superior structures like the market system, governmental authorities or development agencies affect decisions and outputs and finally the overall results that determine food and livelihood security of the group. Species diversity is an aspired output from and a contribution to food and livelihood security.

> *"An urban homegarden, a multispecies production system on the area of land around the house to meet different physical, social and economic needs and functions, is traditionally an important land use activity for individual households. Although its functions are similar throughout the world, focusing principally on subsistence or income generation, their structure and size vary considerably"* (DRESCHER et al. 2006, p. 319).

Since the necessary resources are not always available next to the house, homegardens are often located where land and water are accessible (ibid.). Regarding this definition, the model can be applied to the situation in periurban Hyderabad, where the gardens were not directly located near the houses of the farmers, but next to irrigation sources and provided both for subsistence and income. Biodiversity, made up by *Richness* and *Abundance* (cf. Chapter 4.1.2) is determined by decisions (which crop is planted in what amount) and can therefore be located as livelihood outcome in the model. The *homegarden model* can be used to name and analyse parameters inhibiting or promoting livelihood activities and strategies. DRESCHER et al. (2006, p. 330) describe for instance an analysis of individual homegardens and community gardens in Zambia where agricultural biodiversity differed considerably due to the different management strategies.

Superordinate structures on the macro level can be analysed in this context; the focus in this study is on the micro level, in this case the farming groups (cf. Chapter 3.1). Certain linkages between micro and macro contexts, e. g. the influence of land ownership, are described and discussed (cf. Chapter 4.2.2 and 5.1).

In order to get information about decision making processes and the farmers' livelihood situation, an ethnobotanical approach was chosen for the field work. Ethnobotany provides a holistic approach for understanding the relationship between people and the natural environment taking into account anthropological issues such as livelihoods or vulnerability frameworks as well as natural resources (cf. MARTIN 2004, pp. 2-4).

"*Ethnobotany are all studies (concerning plants) which describe local people's interaction with the natural environment*" (MARTIN cited in COTTON 1996, p. 2). Since the approach comes from social anthropology, it takes into consideration the background of the respective society when looking at natural resources. Methods in ethnobotany are on the one hand taxonomic studies and on the other hand research on traditional knowledge, linguistics and use of the plants through participant long-term observation and interviews (COTTON 1996, pp. 90-127).

The SLA-based homegarden model forms the theoretical background for the interpretation of the data, a system of general structures and processes that can be used to better understand small-scale farming systems in the world and help to analyse a case study with the combined knowledge and results of foregoing research (cf. MAYRING 2007, p. 45). Geography, in this context, facilitates to join different networks, approaches and perspectives from anthropology as well as from natural sciences and provides a platform for analysis and comprehension.

3.2 Fieldwork Methods and Documentation

Regarding controversial discussions and the gaps of knowledge concerning agrobiodiversity and the use of wastewater in irrigated agriculture linked with livelihoods, the aim was to undertake a small field study focussing on vegetables in particular. The research was divided into two parts: On the one hand a mapping of the total area under vegetable cultivation in three periurban villages and the cultivated crops, on the other hand semi-structured, open ended interviews to investigate the farmers' decision making processes and the parameters influencing their choice of crops (cf. COTTON 1996, pp. 92-95). A text was phrased and translated to Telugu to inform the participants about the aims of the observation, that there was no payment and the data was handled confidentially.

3.2.1 The Study Area

Due to the internship the year before the research for this study took place, the infrastructure of the IWMI project could be used. Two periurban villages from this project and one neighbouring village next to the city boundaries along the Musi River were chosen for sampling and mapping of the area under vegetable cultivation (Figure 12).

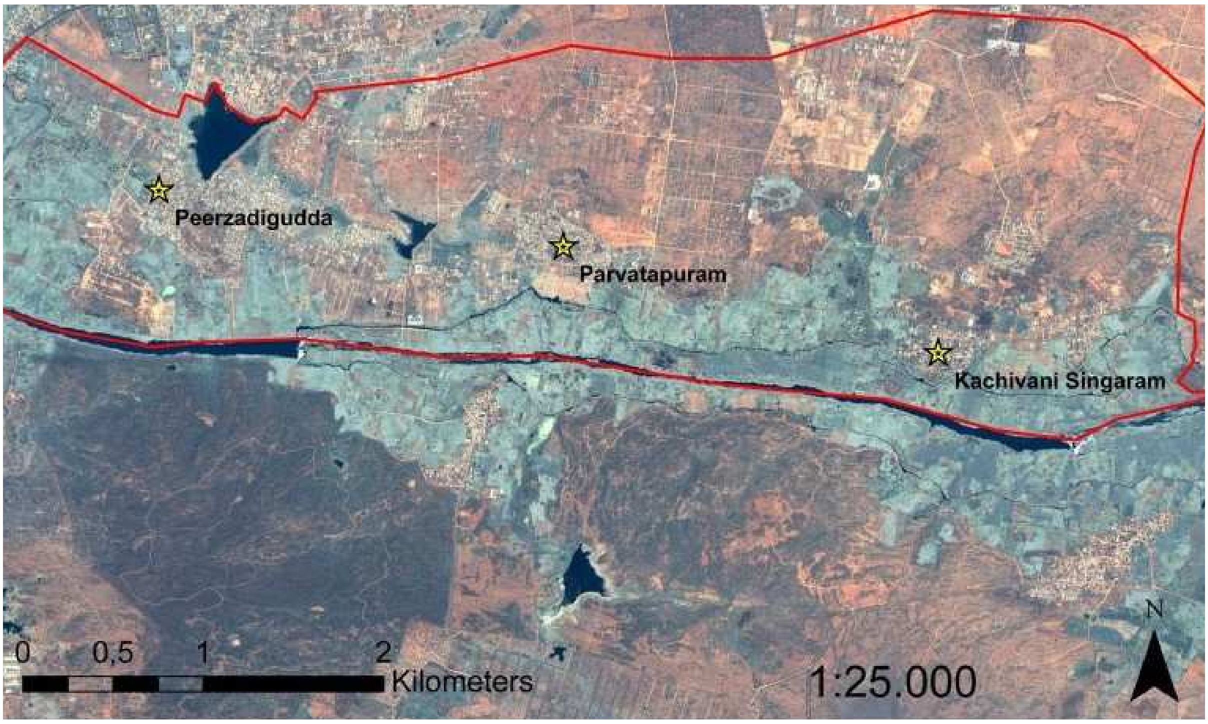

Figure 12: The study site along the Musi River southeast of Hyderabad with the three focus villages. The Hyderabad urban agglomeration begins at the western boundary of the image. Source: QuickBird image 2006, edited in ArcGis

The village boundaries were determined by using data from the IWMI project (for Parvatapuram and Kachivani Singaram) and for the newly added village (Peerzadigudda) which was not covered by the IWMI project, by interviewing the *Sarpanch,* the village head of Peerzadigudda. Demographic data could only be found for the neighbouring village Uppal, by now annexed to the Hyderabad urban agglomeration with a population density of 5,335 persons per km², and the periurban village Qutbullapur (5km from the city, close to Kachivani Singaram) with 4,430 persons per km² in 2001. This compares to a density of 19,149 persons per km² in Hyderabad and to 277 persons per km² in Andhra Pradesh[21]. To identify vegetable gardens, systematic transect walks with informants from the research area were undertaken (cf. CHAMBERS 1992, p. 15).

To avoid confusion, the following **nomenclature** was used:
Garden: one entire, connected vegetable cultivation area
Plot: one individual vegetable field
Sampling Frame: one individual study square (25 to 25 m).
The measurements are mostly quoted in **acres** as usually mentioned by the participants.

[21] Directorate of Economics and Statistics, Andhra Pradesh. Data from Census of India, 2001

Wastewater was classified as either surface water from the Musi River or the sedimentation basin *Nallah Cheruvu* was and **groundwater** as irrigation water pumped from a well[22].

3.2.2 Mapping Agrobiodiversity

In biodiversity discussions, usually three levels are differentiated: Genetic diversity, species diversity and the diversity of ecosystems. For this study, the genetic diversity, in this case the different varieties of vegetables, was important.

Biodiversity referring to species or genetic diversity is determined by two major factors, the number of species (or other categories), and the share of each according to the area (cf. DRESCHER 1998, p. 206). Therefore, at first the extent of vegetable cultivation had to be determined. For this purpose, a village assistant was consulted for each of the research villages to identify the vegetable cultivation areas. Additionally, the *QuickBird* image from 2006 in combination with *Google Earth* images and GIS data from the IWMI project were used to identify possible vegetable fields.

Of the total area under vegetable cultivation in the area of interest, 10% were mapped in detail. The average size of the fields was rather small (on average two to eight meters) and 36 squares of 25 m lateral length were distributed as equally as possible over the entire vegetable area. If the garden was not broad enough, several squares were mapped until an area of 625 m² was covered. For each mapped vegetable variety, individuals were counted in a frame of 50 cm lateral length and then extrapolated for the biodiversity index calculations.

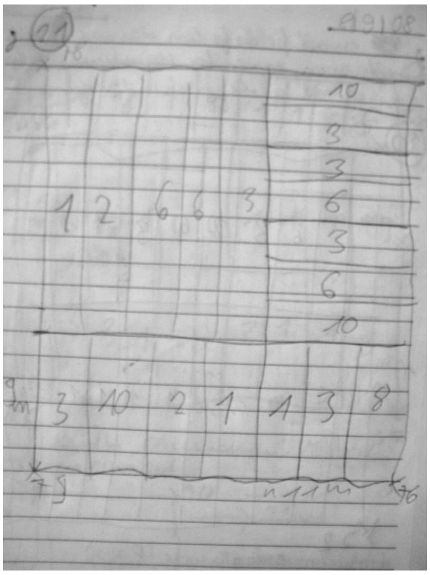

Figure 13: Vegetable garden in the research area with diverse crops. Image by J. Jacobi

Figure 14: Map of a sampling frame with GPS waypoints and crop types

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[22] In the meantime, a sewage plant was constructed in Amberpet upstream to the research area: The Hindu, 7. 9. 2008: “Musi in for better days” available at: http://www.hindu.com/2008/09/07/stories/2008090758930400.htm

The squares were mapped as GPS waypoints and a map was drawn of the squares and each plot they contained. Subsequently, they were divided into a grid by mapping and measuring the most noticeable lines between the small vegetable plots. The sketch of the individual plots was added to the larger grid using visual judgement without measuring each of them. The plots were then given numbers that represent the different vegetable varieties. It was useful to give barren plots a completely different number, like 99, so they could not be confused. On a separate legend sheet, the numbers were connected to vegetable varieties (Figure 14).

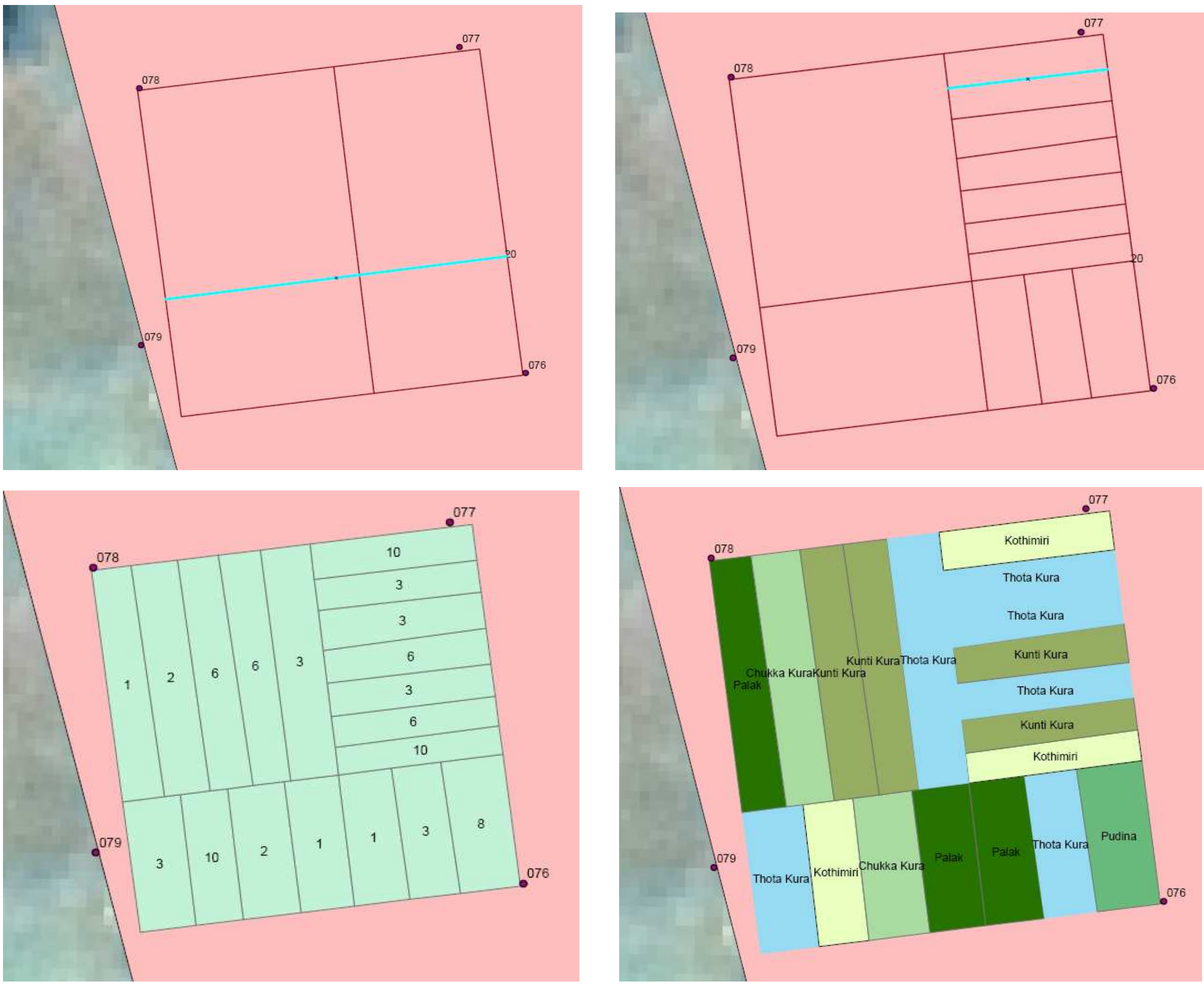

Figure 15: Development of a sampling frame with individual plots in ArcGIS

In *ArcGIS*, the squares were drawn with the aerial photo as the background according to the GPS waypoints and the measurements in the sketch. The boundaries of the sampling frame were drawn as *Polylines* and then converted into *Polygons* ("*create polygons from lines*" in the appending programme *ArcCatalog*). After the fields were named with the numbers and the varieties, the areas could be calculated and displayed.

In order to compare crop diversity in wastewater and groundwater-irrigated gardens, the source of irrigation was also captured if not covered by the GIS data from the IWMI project. Seasonality seemed to be important, as besides summer (*kharif*) and winter (*rabi*), there is the rainy season from August to October and the dry season from May to July which may affect the composition of vegetable varieties. To get an impression of the different crop patterns, three seasonal calendars were developed with the help of farmers during the field mapping, one in a groundwater-irrigated garden and two in wastewater-irrigated gardens (cf. MARTIN 2004, pp. 143-146).

In most of the gardens, flowers like *Marygold* (*Tagetes sp*.) and *Kankarambalu* (*Crossandra infundibuliformis*) were cultivated between the vegetables. They were also grown for the market and used for decoration and religious purposes, but left out in this study because of its focus on vegetables. Fruit trees like Papaya and Banana were not mapped and neither were cereals like paddy and sorghum which are often found in vegetable farming systems e. g. as a winter crop. Of importance for agricultural biodiversity is genetic diversity, which means also diversity within species. Vegetables were therefore distinguished by variety, not by species (cf. Annexe II) which makes more sense to form categories (cf. PEET 1974, p. 286); some were botanically the same species but a different vegetable in the peoples' perception –for instance *Thotakura* (*Amaranthus tricolor*, green variety) and *Koyakura* (*Amaranthus tricolor*, red variety). A herbarium was created after data collection where all local names and attributes were recorded with assistance of the translator. Voucher specimens were collected for the identification of the plants (MARTIN 2004, pp. 28-33).

3.2.3 Farmer Interviews

Thirty informants (Figure 16) were interviewed, each interview taking one to two hours. The interviews were semi-structured and open-ended to give the interviewees the chance to report and to detail topics that were important to them (cf. MARTIN 2004, p. 96 and ATTESLANDER 2008, p. 124). During the foregoing mapping, questions were developed, the questionnaire pre-tested and adapted according to what emerged during the discussions with the participants (see Annexe II). Semi-structured interviews "*regarded by some as the good core of RRA [rapid rural appraisal] (…) can entail having a mental or written checklist, but being open-ended and following up to the unexpected*" (CHAMBERS 1992, p. 15). With the interviews, preference rankings were carried out (ibid., p. 17 and 29, COTTON 1996, pp. 97-99) to find out which factor is more important for decision making. Another highlighted aspect was the acquisition of knowledge to find out how farmers could be reached with extension programmes and how important traditional agricultural knowledge was. Again, a ranking was formed after the importance of the different knowledge sources.

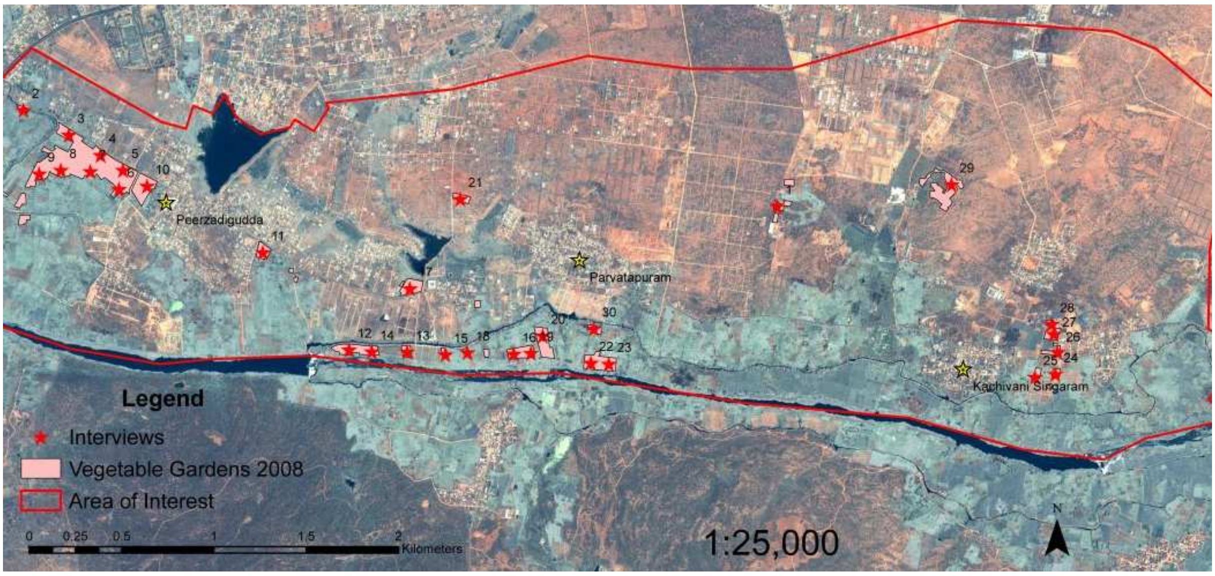

Figure 16: Spatial distribution of the 30 interviews in the research area

In order to get a broad overview, the selected informants were not only male household heads or only women but also anyone representing a farming group (cf. COTTON 1996, p. 103). Emphasis was put on an equal distribution of farmer interviews in the research area. Very commonly, one farming group worked on one quarter of an acre so that the distribution was on a very small scale. The case of the groundwater-irrigated gardens was different (less people working on more land with external labour during harvest times). This is why the distribution of the interviews was not totally equal: It appeared to be not useful for this purpose to interview more than one person of one farming group since the information gathered referred to one entire farming group. The conversation was not tape-recorded but written in a field notebook, since people might be reticent to freely express their opinions when they are being recorded (cf. MARTIN 2004, p. 112).

One key informant who was visited several times was able to give in-depth interviews and valuable information about the general situation of smallholder farmers in India (cf. MARTIN 2004, p. 96). Since he had experience of more than 60 years of (organic) farming, he was in a position to give an insight to periurban farming systems. There was time for questions that could not be addressed in all the interviews, e. g. about the role of agricultural extension services and why they were unknown to most of the interviewees, or traditional organic pest management and the use of compost and intercropping.

3.3 Tools for Data Analysis

For the identification of the vegetables and taxonomy, the FAO database *Hortivar* was used. The database *Food Plants International* provides even more information, mainly about uncommon and indigenous vegetables. Another helpful publication for the South Indian context was *Nourishing Traditions - Local Greens* published in 2006 by the *Andhra Pradesh Farmer Managed Groundwater Systems Project* where most of the leafy vegetables could be found with descriptions of their nutritional contents and use. AVRDC publications and staff who helped to identify the voucher specimens, the publications TINDALL (1983): *Vegetables in the Tropics* as well as PURSEGLOVE (1974): *Tropical Crops, Dicotyledons* and GIBBON & PAIN (1985): *Crops of the Drier Regions of the Tropics* were useful for taxonomy.

The programme *Google Earth* provided the opportunity to compare old and new satellite images starting in 2003. From the IWMI project, a *QickBird* satellite image from 2006 was available. All maps were produced in *ArcGIS 9. 2* and all the data was stored in a database in the GIS for spatial analysis and calculations.

To calculate biodiversity, the programme *BioDiversity Pro* developed by the *Museum of Natural History* of London which could be downloaded free of cost was used. Further calculations and descriptive statistics were carried out in *Microsoft Excel.* For the interviews, the programme *MAXQDA* for professional text analysis contributed to the content analysis (cf. ATTESLANDER 2008, p. 207). The evaluation procedure was carried out following MAYRING (2007): Qualitative *Content Analysis* was used to reduce the material in order to keep essential contents while creating a manageable overview (cf. MAYRING 2007, pp. 59-63).

3.4 Difficulties during the Fieldwork

Dynamics of interviews are always influenced by all participants, not only the interviewee but also the translator and the interviewer, by differences in gender, age, social status etc. (MARTIN 2004, p. 111). The language barrier was the most obvious problem especially during the interviews. For the mapping, a person with agricultural knowledge assisted for the communication with the farmers. However, persons who are familiar with the topic could be tempted to include their own knowledge and interpretation in the translation which would not reflect the farmers' point of view (cf. COTTON 1996, pp. 107-108). To avoid this, a young female teacher from the research area was consulted for translation during the interviews. The shifting from one translator to another was difficult, but for the first visits and the mapping it was useful to be accompanied by somebody with agricultural knowledge, for the interviews it was an advantage to be with a person of the same gender and age from one of the villages in the study area. The risk of discontinuity in the survey could be reduced by going to the field several times with both translators.

In some cases, many people joined the interviews after some time and group discussions developed which may have had an impact on the content of the answers.

The interviews were based on farming communities engaging in one garden which were mostly families. Therefore, most of the respondents were male because they represent the family to foreign people and usually manage most of the decision making and marketing (cf. interview outcomes Chapter 4.2).
The interviewed farmers seemed to be afraid of too much official attention paid to wastewater irrigation, while they were trying to hide the practice in the markets from the customers who were warned against food products produced with polluted water by several television reports according to the farmers (a fact that was also mentioned in a case study from Accra, Ghana, ADJAYE-GBEWONYO 2008). Furthermore, the long interviews kept farmers away from work not offering any direct benefits for them. Another issue was the extractive character of research without a direct impact and benefit for the participants. Some respondents asked for direct help and support, being tired of participating in surveys without benefit.
To avoid sources of errors for instance by not following the principles of random sampling, the interviews were distributed as equally as possible and took place during different times of day. However, the outcomes can only be an approach to reality, since it cannot be granted that further sources of error were obviated (cf. ATTESLANDER 2008, p. 261).

4 Outcomes: Agrobiodiversity and Decision making in Periurban Hyderabad

4.1 Mapping Outcomes: Extent of Vegetable Cultivation and Garden Structure

The study area covered three periurban villages and an area of 2,853.4 acres or 11.55 km²: *Peerzadigudda, Parvatapuram* and *Kachivani Singaram* along the northern side of the Musi River. An area of 54.84 acres or 1.92% of this area was under vegetable cultivation at the time of the mapping in 2008. This is an increase of 19.6% as compared to the satellite image and the mapping undertaken from 2006 to 2008 (2006: 1.61%). For Peerzadigudda and Parvatapuram, mappings from 2002 were also available (KRISHNAGOPAL & SIMMONS 2007, p. 35). Using satellite images from 2002 and 2006 and the mapping data from 2008, the extent could be calculated and displayed using ArcGIS. However, for the year 2002 available data covered only Peerzadigudda and Parvatapuram. For Kachivani Singaram, the interview information *since when cultivation is practiced, and since when in this place* was used without claiming completeness as it remains unknown if somebody has abandoned cultivation in the meantime. In spite of different perceptions (statements of three participants that vegetable cultivation decreased), the increase of the extent of the area of vegetable cultivation from 2002 to 2008 is considerable (Figure 17 a, b, c): **From 21.93 acres in 2002 to 45.85 acres in 2006 to 54.84 acres in 2008**, which poses an **increase of 150% between 2002 and 2008** based on the extent of 2002.

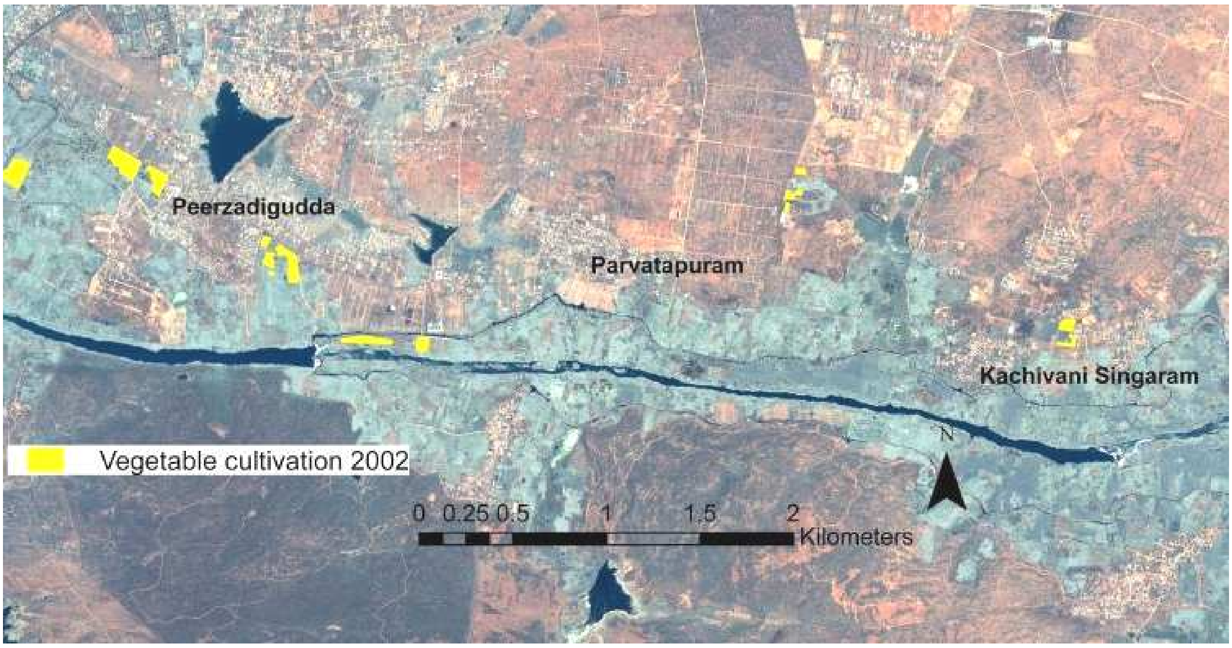

Figure 17a: Total area under vegetable cultivation in the study area in 2002, according to mapping data, satellite images and interviews

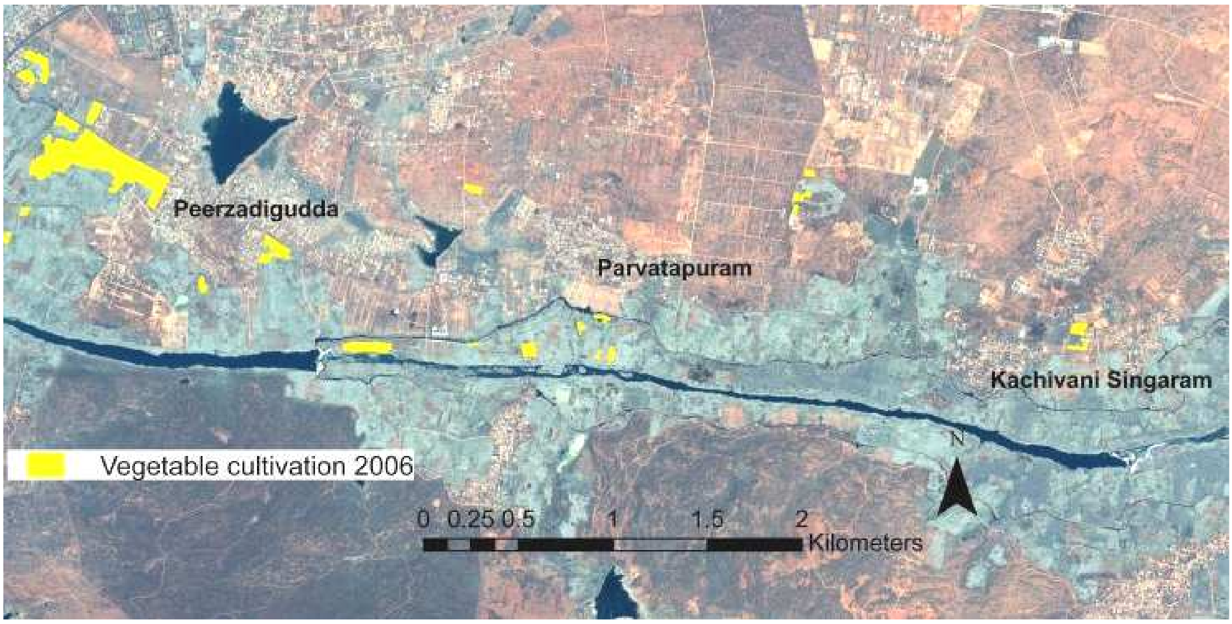

Figure 17b: Total area under vegetable cultivation in the study area in 2006, mapping in ArcGIS

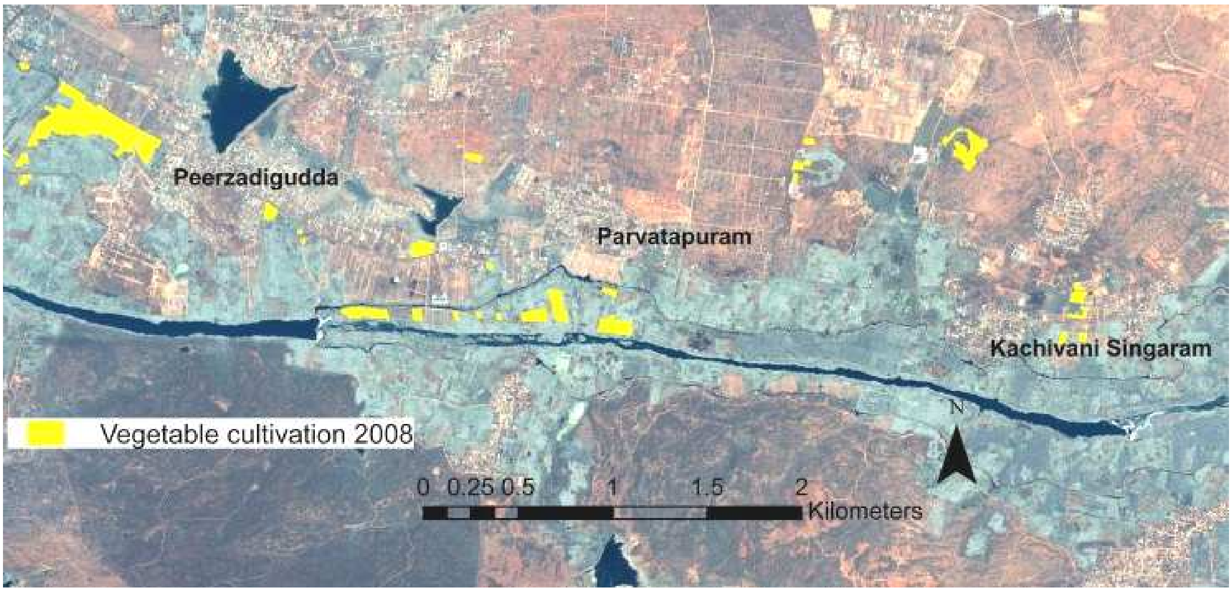

Figure 17c: Total area under vegetable cultivation in the study area in 2008, mapping in ArcGIS

The findings are comparable to results from earlier studies on vegetable cultivation in and around Hyderabad: KRISHNAGOPAL & SIMMONS (2007, p. 11) found an increase of 187.9% from 13.74 acres in 2002 to 39.58 acres in 2006 of wastewater-irrigated areas under vegetable cultivation by remote sensing. The research area covered three periurban and three rural villages along the Musi River near Hyderabad, two of which (Parvatapuram and Kachivani Singaram) were also study sites of this observation as mentioned before.

Figure 18: Woman harvesting spinach, Peerzadigudda, September 2007. Image by J. Jacobi

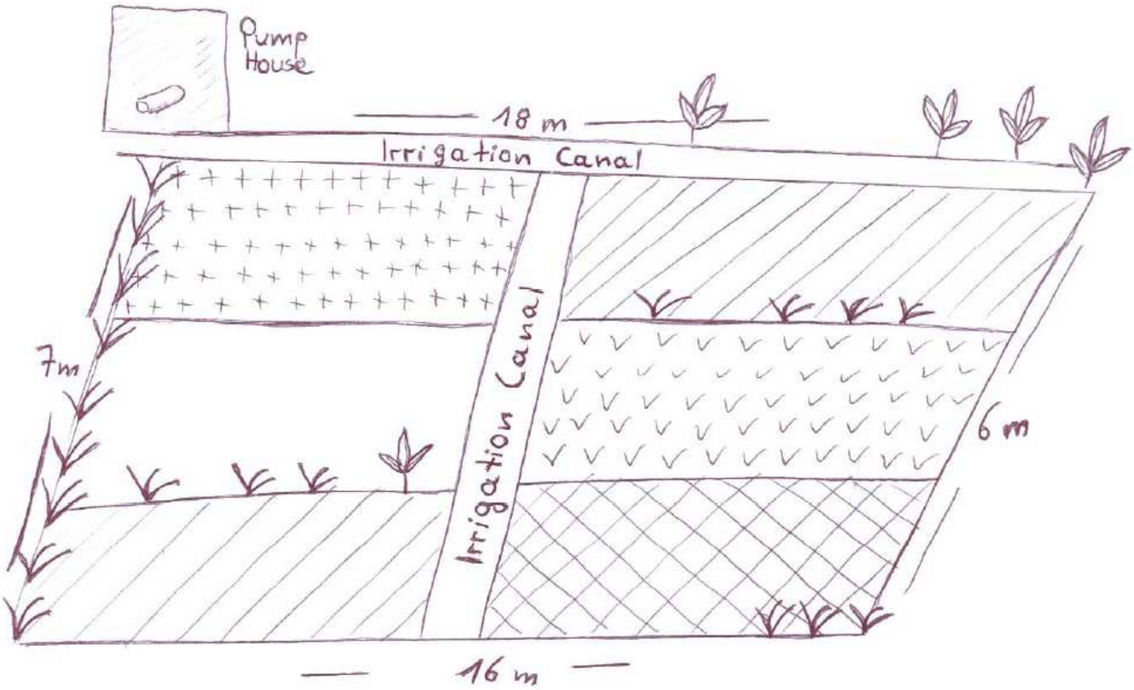

Figure 19: Sketch of a vegetable garden in Parvatapuram

As the schematic drawing illustrates, the small plots were framed by irrigation canals. Between the plots, mostly cultivated with leafy vegetables, taller plants were grown, either for seeds (e. g. amaranth), for tubers and leaves (taro, sweet potatoes) or perennial plants (*Chennangi*). Also, single chili or tomato plants or legumes could be found between plots.

4.1.1 Vegetables Cultivated in the Study Area

Fifty-four varieties of vegetables from twenty plant families were mentioned by the farmers and mapped in Peerzadigudda, Parvatapuram and Kachivani Singaram (complete list see Annexe I). Among these, 18 (including cabbage) were cultivated for the leaves most of which were usually cooked like spinach.

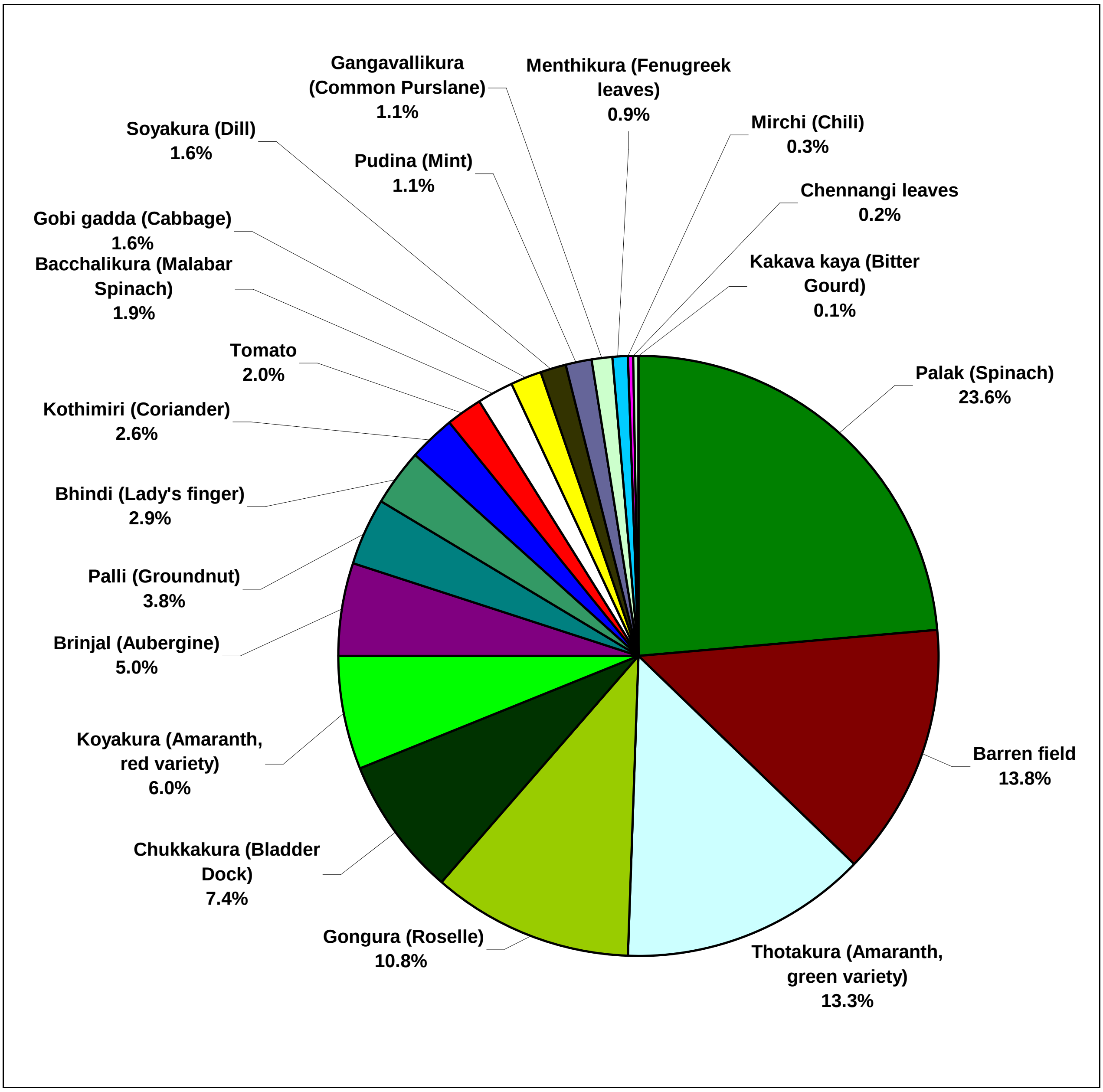

Figure 20: Share of vegetables cultivated in the research area, names in Telugu (English in brackets)

In Figure 20, the distribution of the vegetables on the mapped area is displayed. Only 19 out of the 31 mapped vegetable varieties in the sampling frames are shown since the rest ranked below 0.1% of the area (due to intercropping and being cultivated in lines besides the plot for seed production or self-consumption). Among these 19 mapped varieties, 12 were cultivated for the leaves. The large fraction of barren fields shows the constant circulation between harvesting and sowing, often in a rotation of two weeks, thus the fallow land is part of the crop rotation system. The seasonal aspect had to be considered: Three seasonal calendars showed that due to constant water availability, vegetables were cultivated throughout the year with fluctuations in the share of each.

Nutrients and contents of vegetables are described in a publication on leafy vegetables by the FAO-funded *Andhra Pradesh Farmer Managed Groundwater Systems Project* (APFMAGS 2006):

Table 3: Important nutrients in vegetables and their use. Source: APFMAGS 2006, p.19

"Carbohydrates: To provide energy needed to keep the body breathing, for movement and warmth, for growth and repair of tissues. Some starch and sugar is changed to body fat.
Dietary fibre: Fibre makes faeces soft and bulky and absorbs harmful chemicals, and so helps to keep the gut healthy. It slows digestion and absorption of nutrients in meals, and helps to prevent obesity.
Fats: To provide a concentrated source of energy and the fatty acids needed for growth and health. Fat aids the absorption of some vitamins such as vitamin A.
Proteins: To build cells, body fluids, antibodies and other parts of the immune system. Sometimes proteins are used for energy.
Iron: To make haemoglobin, the protein in red blood cells that carries oxygen to the tissues. To allow the muscles and brain to work properly
Vitamin A: To prevent infection and to keep the immune system working properly. To keep the skin, eyes and lining of the gut and lungs healthy. To see in dim light.
B-group vitamins: To help the body use macronutrients for energy and other purposes. To help the nervous system to work properly.
Folate: To make healthy red blood cells and to prevent abnormalities in the foetus.
Vitamin C: To aid the absorption of some forms of iron. To develop resistance against diseases in the body. To help wound healing.
Calcium: For strong bones and teeth."

In India, around 75% of preschool children suffer from iron deficiency and 57% from vitamin A deficiency (GRAGNOLATI et al. 2005, p. 19, also cf. Table 1 and Chapter 2.1). The WHO (2003a, p. 18) stated that "*vitamin A deficiency remains the single greatest preventable cause of childhood blindness and increased risk of premature childhood mortality from infectious diseases*". To eliminate vitamin A deficiency and its consequences by 2010 is one of the major aims of the WHO[23]. The *Indian Council of Medical Research* found that "*by encouraging the consumption of green, leafy vegetables among the people in the poor communities and without introducing any other change in their diets, the incidence of vitamin A deficiency can be lowered considerably*"[24]. Food plants in the research area particularly high in beta carotene (a form of vitamin A) were: *Palak (Spinacea oleracea), Koyakura* and

[23] " the UN Special Session on Children in 2002 set as one of its goals the elimination of vitamin A deficiency and its consequences by the year 2010". http://www.who.int/vaccines/en/vitamina.shtml

[24] Indian Council of Medical research, Hyderabad: "Absorption of ß-carotene from green leafy vegetables in undernourished children". http://www.ajcn.org/cgi/content/abstract/23/1/110

Thotakura (*Amaranthus sp*., green and red variety), *Chamakura* (*Colocasia esculenta*), *Menthikura* (*Trigonella foenum-graecum*) and *Chennangi* (*Lagerstroemia parviflora*) (cf. APFMAGS 2006, p. 27).
In the following, selected vegetables found in the area of interest are introduced. Spinach as the predominant vegetable in the research is not referred to in favour of less known varieties. Information from literature is backed up with content analysis from the interviews about inputs, time from sowing until harvest and medical use.

<u>*Amaranthus tricolor* (L., Amaranthaceae)</u>

Figure 21: Varieties of *A. tricolor* (L.) Source: AVRDC 2003

This annual cosmopolitan, also known by the pejorative names *Pigweed* or *Poor Man's Spinach*, is widely cultivated and consumed in traditional farming systems in the tropics. The seeds are edible as well as the stems and leaves. *A. tricolor* (the green variety is known as *Thotakura*, the red variety as *Koyakura* in the research area) is synonymous with *A. blithum and A. gangeticus* although taxonomy is complicated due to hybridisation. Amaranth needs soils with high organic matter content, is tolerant to high temperatures, humid and arid climates, a wide range of soil conditions and can be grown both in the dry and the rainy season. The plant uses the C 4 metabolism for photosynthesis (TINDALL 1983, p. 36). As TINDALL (1983, p. 39) points out, the leaves can be harvested 30-50 days from sowing, but in the fieldwork for this study, farmers reported 15-30 days after the first cut due to the highly nutritious irrigation water. Amaranth leaves are high in vitamin A and C, calcium, iron and potassium as an essential mineral micronutrient (TINDALL 1983; AVRDC 2003; APFMAGS 2006).

Nutrient	Value per 100g	
Protein	4.0	g
Fat	0.5	g
Minerals	2.7	g
Fibre	1.0	g
Carbohydrate	6.1	g
Energy	45	Kcal
Calcium	397	mg
Phosphorous	83	mg
Iron	3.5	mg
Beta carotene	8,340	µg
Thiamin	0.03	mg
Riboflavin	0.30	mg
Niacin	1.2	mg
Vitamin-C	99	mg
Folate	149	mg

Figure 22: Nutrients in amaranth (APFMAGS 2006, p. 25), red (Koyakoora) and green (Thotakura) variety of *Amaranthus tricolor*. Image by J. Jacobi

Hibiscus acetosella var. sabdariffa **(L., Malvaceae)**

Nutrient	Value per 100g	
Protein	1.7	g
Fat	1.1	g
Minerals	0.9	g
Fibre	-	-
Carbohydrate	9.9	g
Energy	56	Kcal
Calcium	172	mg
Phosphorous	40	mg
Iron	2.3	mg
Beta carotene	6,970	µg
Thiamin	0.07	Mg
Riboflavin	0.39	Mg
Niacin	1.1	NE
Vitamin-C	20	Mg

Figure 23: Roselle (*Hibiscus acetosella var. sabdariffa*), source: APFMAGS 2006, p. 55

Cultivated on more than 10% of the mapped area, *Gongura* or *Puntikura*, as roselle is called in Telugu, ranked 3rd of all vegetables in the research area. The plant is believed to originate in Central or West Africa. Today, it is widespread in tropical areas and can be grown on poor soils. Young shoots and leaves from both red and green varieties are harvested after 15-30 days (as reported in the interviews) and usually cooked as a sour tasting side dish, which is very high in beta carotene (cf. TINDALL 1983, p. 332 and APFMAGS 2006). In other regions, the calyces of the flower are boiled with sugar for a drink. The plant tolerates moderately fertile sands and responds well to nitrogen fertilizer although it is not necessary (GIBBON & PAIN 1985, p. 61). In the interviews it was mentioned that *Gongura* needs no fertilizer at all, but regular irrigation is required.

Basella alba var. rubra (Moq., Basellaceae)

B. alba var. rubra is commonly known as Malabar or Ceylon spinach *(Bacchali* in Telugu) and native to tropical Asia. It is a perennial plant but was cultivated as a short-term crop around Hyderabad. One plant provided up to 10 harvests and *Bacchali* was reported to require no fertilizer but high input costs due to expensive seeds. Like amaranth, the plant has a C 4 cycle photosynthetic pathway to make optimal use of the tropical sunlight (TINDALL 1983, p. 69). It is relatively resistant to pests and diseases, tolerant to many soil conditions and therefore adequate for small-scale production in homegardens and commercial gardens. It requires weekly irrigation and can be harvested after 30-45 days according to the AVRDC, but in this study, farmers reported 15-30 days. The stems and leaves are cooked in oil with spices and are rich in iron, calcium and vitamin A and C (AVRDC 2003, TINDALL 1983 p. 70).

Nutrient	Value per 100g	
Protein	2.8	g
Fat	0.4	g
Minerals	1.8	g
Carbohydrate	4.2	g
Energy	32	Kcal
Calcium	200	mg
Phosphorous	35	mg
Iron	10.0	mg
Beta carotene	2,840	µg
Thiamin	0.03	mg
Riboflavin	0.16	mg
Niacin	0.5	mg
Vitamin-C	87	mg

Figure 24: Nutrients in Malabar spinach (source: APFMAGS 2006, p. 57), *Basella alba var. rubra* (source: AVRDC 2003)

Portulaca oleracea (Portulaceaceae)

The common purslane or *Gangavallikura* in Telugu is a succulent annual and grows in a dense mat. It is reported to contain bioprotective nutrients and high vitamin values. It has small, single yellow flowers and is regarded as a weed in other regions of the world according to the *University of California*[25]. *Gangavallikura* was reported to be only harvested once from one package of seeds after 15-30 days and to be planted during summer (*kharif*).

[25] University of California, Integrated Pest Management. More information: http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7461.html

Nutrient	Value per 100g	
Protein	2.4	g
Fat	0.6	g
Minerals	2.3	g
Fibre	1.3	g
Carbohydrate	2.9	g
Energy	27	Kcal
Calcium	111	mg
Phosphorous	45	mg
Iron	14.8	mg
Carotene	2,292	µg
Thiamin	0.10	mg
Riboflavin	0.22	mg
Niacin	0.7	mg
Vitamin-C	29	mg

Figure 25: Gangavallikura (*Portulaca oleracea*), source: APFMAGS 2006, p. 139

Rumex vesicarius **(L., Polygonaceae)**

Nutrient	Value per 100g	
Protein	1.6	g
Fat	0.3	g
Minerals	0.9	g
Fibre	0.6	g
Carbohydrate	1.4	g
Energy	15	Kcal
Calcium	63	mg
Phosphorous	17	mg
Iron	0.8	mg
Beta Carotene	2,800	µg
Thiamin	0.03	mg
Riboflavin	0.06	mg
Niacin	0.2	mg
Vitamin-C	12	mg
Folate	125	mg

Figure 26: Chukkakura (*Rumex vesicarius*), source: APFMAGS 2006, p. 35

Chukkakura or bladder dock is very tolerant to different soil conditions under regular irrigation. It contains oxalic acid which is reduced by cooking. The leaves and stems are cooked in curries or chutneys (pickles), the young shoots can also be eaten raw. *Chukkakura* in the research area could be harvested 1-5 times from one package of seeds every 15-30 days. The plant could be cultivated throughout the year (eight respondents) but required more fertilizer than other leafy vegetables according to five respondents.

Figure 27: Farmer harvesting Chukkakura in Peerzadigudda, Oct. 2008, image by J. Jacobi

Trigonella foenum-graecum **(L., Fabaceae)**

Nutrient	Value per 100g	
Protein	4.4	g
Fat	0.9	g
Minerals	1.5	g
Fibre	1.1	g
Carbohydrate	6.0	g
Energy	49	Kcal
Calcium	395	mg
Phosphorous	51	mg
Iron	1.93	mg
Beta carotene	9,100	µg
Thiamin	0.04	mg
Riboflavin	0.31	mg
Niacin	0.8	mg
Vitamin-C	52	mg

Figure 28: Fenugreek (*Trigonella foenum-graecum*), source: APFMAGS 2006, p. 53

Fenugreek is known as *Menthikura* in South India and the leaves are used as well as the seeds. The farmers interviewed in periurban Hyderabad cultivated it for the leaves, which were harvested after 20 days. Even though the plant required less fertilizer than others, it was considered as a high input crop by the farmers ("*Menthikura seeds are more expensive than others; therefore I cultivate less of this vegetable"*). According to APFMAGS (2006, p. 53) it is a winter crop which was confirmed in the mapping where it was found from October. The leaves are believed to *"cure blood motions, increase digestion and cool the body"* (ibid.).

Lagerstroemia parviflora **(Roxb., Lythraceae)**

Nutrient	Value per 100g	
Protein	8.5	g
Fat	1.3	g
Minerals	3.6	g
Fibre	3.3	g
Carbohydrate	15.9	g
Energy	109	Kcal
Calcium	882	mg
Phosphorous	125	mg
Iron	10.7	mg
Beta Carotene	9029	µg
Vitamin-C	260.85	mg

Figure 29: Chennangi (*Lagerstroemia parviflora*), source: APFMAGS 2006, p. 81

Chennangi (no English name could be found) is a perennial, lignifying plant. Therefore it was usually grown in lines and rarely in the plots where crop rotation was practiced. It is cultivated for the leaves which are very high in beta carotene and vitamin C. In other regions of the world, the sweet gum from cuts in the bark is eaten (Food Plants International, 2008).

Coriandrum sativum **(L., Apiaceae)**

Nutrient	Value per 100g	
Protein	3.3	g
Fat	0.6	g
Minerals	2.3	g
Fibre	1.2	g
Carbohydrate	6.3	g
Energy	44	Kcal
Calcium	184	mg
Phosphorous	71	mg
Iron	1.42	mg
Beta carotene	4,800	µg
Thiamin	0.05	mg
Riboflavin	0.06	mg
Niacin	0.8	mg
Vitamin-C	135	mg

Figure 30: Coriander (*Coriandrum sativum*), source: APFMAGS 2006, p. 45

Coriander is native to the Mediterranean region but very popular in South Asia where the fresh leaves are added to many dishes as a spice. The seeds are also used as a spice. Coriander requires a well-drained, fertile soil and leaves can be harvested after 35-45 days (TINDALL 1983, p. 404). As they are consumed raw, there is a certain risk of pathogen transmission when irrigated with polluted water. *Kothimiri* is reported to *"cool the body, help in easy digestion, clear lungs and make breathing free"* (APFMAGS 2006, p. 45). One farmer reported having abandoned cultivating *Kothimiri* "*because of high seed costs*", and three others also mentioned high seed prices for coriander. Only one participant reported to cultivate the seeds himself.

***Colocasia esculenta* (L., Araceae)**

Nutrient	Value per 100g	
Protein	3.9	g
Fat	1.5	g
Minerals	2.2	g
Fibre	2.9	g
Carbohydrate	6.8	g
Energy	56	Kcal
Calcium	227	mg
Phosphorous	82	mg
Iron	10.0	mg
Beta carotene	5,920	µg
Thiamin	0.22	mg
Riboflavin	0.26	mg
Niacin	1.1	mg
Vitamin-C	12	mg

Figure 31: Taro leaves (*Colocasia esculenta*), source: APFMAGS 2006, p. 43

The highly polymorphic taro, or *Chamakura* (in Telugu), is cultivated for tubers and leaves. In the research area, the tubers were purchased in markets and then planted between the vegetable plots or along irrigation canals, where the leaves could be harvested on demand; removing parts of the tubers does not harm the perennial plant. It is believed to be native to India and today widespread in the tropics. It is of importance to household food security since it provides constant yields. However, the consumption decreases steadily as it is gradually replaced by maniok and sweet potato (cf. TINDALL1983, p. 52). It was considered as a low-input crop by the participants.

***Momordica charantia* (L., Cucurbitaceae)**

Figure 32: Bitter gourd (*Momordica charantia*) in a market. Image by J. Jacobi

Adavika Kaya, as the common bitter gourd is called in Telugu, is both a monoecious or dioecious annual climber. One month after planting, the first flowers appear and the fruits are ripe 20 days later. It is widely grown in South Asia, where usually the young fruits and leaves are cooked. Bitter gourd is also used in native medicines (PURSEGLOVE 1974, p. 132). The plant contains quinine and is said to be effective against viral diseases, (Food Plants International 2008). The seeds of all cucurbits were regularly reported to be produced by the farmers themselves, but also purchased.

***Vigna mungo* (L., Fabaceae)**

Figure 33: Black gram (*Vigna mungo*), source: AVRDC 2003

Legumes play an important role in India due to their use in *Dhal*, a lentil soup with different ingredients which provides proteins to the mostly vegetarian dishes. Legumes (Fabaceae) host rhizobia (soil bacteria) in their roots which are able to fix atmospheric nitrogen (N_2) to plant-available ammonium (NH_4) and are therefore often included in cereal-based cropping systems to maintain soil fertility. Even under relatively acid conditions, phosphorus and calcium deficiency, the roots of many leguminous crops can host rhizobia (TINDALL 1983, p. 250). The plant can also be used as a green manure (cf. AVRDC 2003). Black gram or *Minapa Pappu* in Telugu is an annual, bushy herb and drought resistant and therefore an adequate *kharif* crop, which grows on a wide range of soils (GIBBON & PAIN 1985, p. 109). Green pods can be harvested 2-4 months after sowing and are highly nutritious. Dried seeds contain 24% of protein and are high in vitamin C (TINDALL 1983, p. 293). They are ground for flour for bread and porridge. Almost the entire Indian production is for local use (GIBBON & PAIN 1985, p. 109).

4.1.2 Agrobiodiversity in the Research Area

In ecologic research, biodiversity is generally expressed by two parameters: The number of species and the number of individuals in each species category (cf. DRESCHER 1998, p. 206; MÜHLENBERG 1993, p. 353). Both have to be related to the specific area. In other words, the two main factors taken into account are *abundance* or *richness* (for instance species richness: The number of different species in a habitat), and *evenness*, the relative abundance of the species in the habitat. For instance, in a community with 99 grass individuals and one daisy, the evenness (and diversity) is less than in a habitat with 50 grass plants and 50 daisies (cf. HILL 1973; PEET 1974).
Two major indices to measure biodiversity are used: the *Simpson's Index of Diversity*[26] (measuring proportional abundance) and the *Shannon-Index*[27] (measuring evenness, equitability and proportional abundance, SMALE 2007, p. 9). These indices are widely used for measuring agricultural biodiversity (ibid.) and in this study both were used to compare the different findings in wastewater and groundwater-irrigated samples.

The *Simpson's Index of Diversity* calculates the likeliness that two incidentally picked individuals from a certain habitat belong to the same category (in this case study vegetable variety).

The formula for an infinite population would be: $$D = \sum (n/N)^2$$

In the case of sampling, like in this study, the formula is:

[26] First published in Nature vol. 16, 1954: „Measurement of Diversity“

[27] Also *Shannon-Weaver-Index* or *Shannon-Wiener-Index*.

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

With n = sum of individuals from one category
And N = sum of individuals from all categories

Source: SIMPSON 1949, p. 688, modified

If the result is zero, diversity is infinite and if it is one, a monoculture: The higher the result, the smaller is the diversity. This is not very intuitive and therefore it is common to subtract the result from 1. Therefore, the *Simpson's Index of Diversity* is **1- D.**

***Simpson's Index of Diversity* for the research area:**

Total		**Groundwater**		**Wastewater**	
SD=	**0.76**	**SD=**	**0.75**	**SD=**	**0.77**

The *Shannon-Index* uses similar parameters and a different formula, including the natural logarithm and the number of categories (cf. DRESCHER 1998, p. 206):

$$H_s = -\sum_{i=1}^{S} p_i \ln p_i$$

Hs = Shannon-Index
S = number of categories in a habitat
p_i = share from one category in the total number of categories

Source: SHANNON & WEAVER 1963, modified

Shannon-Index for the research area:

Total: S=31		**Groundwater: S=21**		**Wastewater: S=16**	
Hs=	**1.85**	**Hs=**	**1.75**	**Hs=**	**1.71**
Hmax=	**3.43**	**Hmax=**	**3.04**	**Hmax=**	**2.77**
Evenness:	**0.54**	**Evenness:**	**0.57**	**Evenness:**	**0.62**

Results: Using the *Simpson's Index of Diversity,* diversity was higher in wastewater-irrigated gardens but the difference was only 2.0 %. With the *Shannon-Index,* it was slightly higher in groundwater-irrigated gardens, with a difference of 2.3 %. This happens as the formulas are

to some extent different: The *Simpson's Index of Diversity* shows the heterogeneity (or likeliness that two individuals are from the same category) in percent, the *Shannon-Index* is a numeric value of diversity compared to the maximum capacity (Hmax) of biodiversity, which increases with the number of categories. The difference results from this different way of demonstration: Compared to Hmax, Hs in the wastewater-irrigated gardens was higher (the total number of varieties was less that in groundwater-irrigated gardens, where Hmax was higher, but the evenness was less). However, **the difference between groundwater and wastewater irrigation in evenness and richness was not significant** (less than 5% deviation, cf. BAHRENBERG & GIESE 1975, pp. 98-99; also cf. the t-test in Annexe III).
The Hypothesis "*agricultural biodiversity is lower when wastewater is used for irrigation than when groundwater is used*" is therewith not appropriate for the case of the research area in periurban Hyderabad.

Since agricultural biodiversity did not differ much in the indices calculations, another formula was used to calculate the **similarity** (ß-divesity) of the species composition in the two different agroecological systems (SØRENSEN 1948). The *Sørensen Similarity Coefficient* (S) is composed of the number of species only in **habitat a** (gardens irrigated with wastewater), the number of species only in **habitat b** (gardens irrigated with groundwater) and those found in both **habitats (c)**:

$$S = \frac{2c}{(2c + a + b)} * 100\% \qquad \mathrm{S} = 24 / (24 + 9 + 4) * 100 = 64.8\%$$

From this result, the samples cannot be considered as dissimilar (only if S = < 50%), but regarding the area cultivated with the vegetables in question, it becomes obvious that most of the species common in both irrigation systems covered less than 5% of the land. The *Sørensen Similarity Coefficient* does not take the area into account. If one compares the five most important varieties which made up 82.3% of the area irrigated with wastewater and 78.5% in groundwater-irrigated areas, only one (*Hibiscus acetosella*) was found in both samples. From this point of view, the **species composition differed significantly** (S = 20%), which was also approved by a t-test (cf. Annexe III).

4.1.3 Comparison of Diversity in Groundwater and Wastewater-Irrigated Gardens

Figure 34: Wastewater irrigation along the Musi River, October 2008. Images by J. Jacobi

The results of the mapping indicate that there was no significant difference in agrobiodiversity between wastewater and groundwater-irrigated periurban vegetable gardens near Hyderabad. The significant difference was in the species composition: As Figures 35 and 36 show, farmers using wastewater relied mostly on leafy vegetables (94.75% of the sampled area) for several reasons discussed in Chapter 5.1, whereas those using groundwater from a well cultivated mostly fruit bearing vegetables (73.81%).

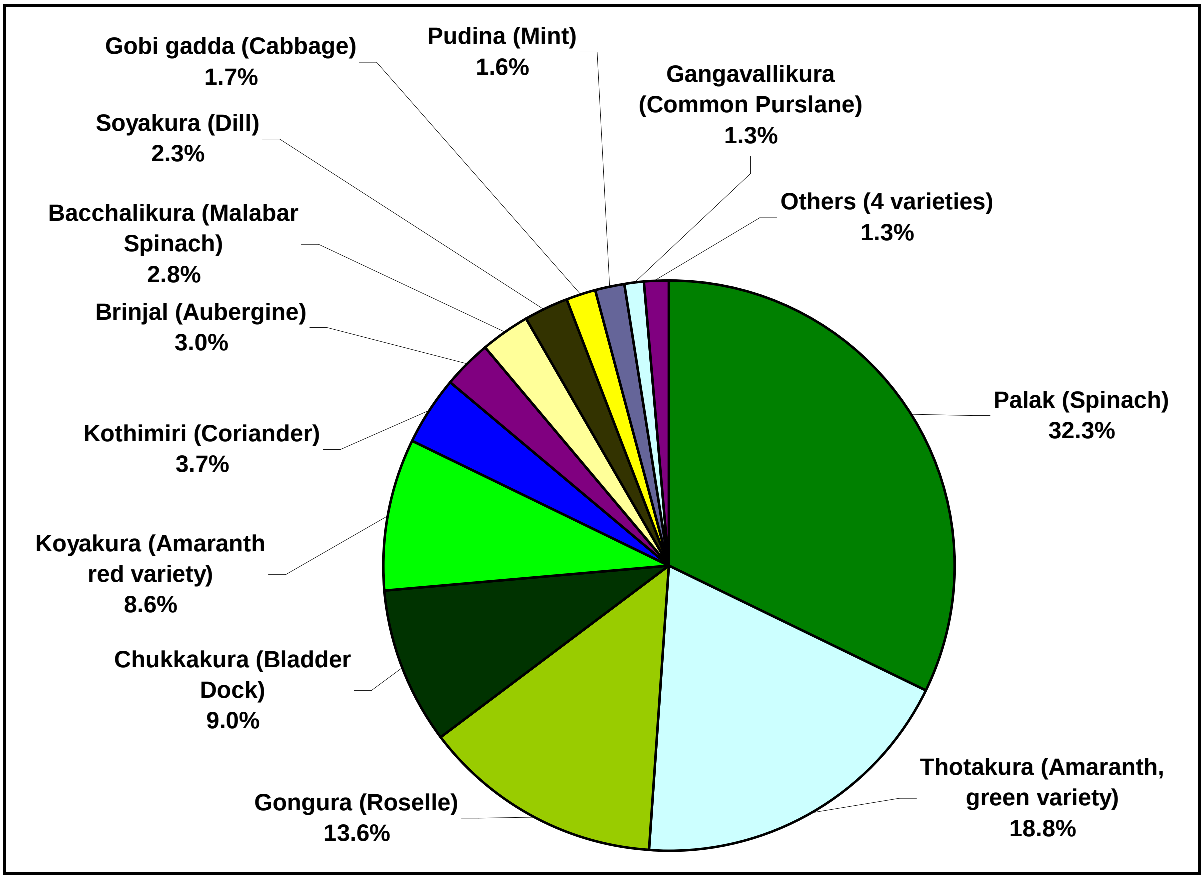

Figure 35: Share of vegetables in wastewater-irrigated gardens, September/October 2008

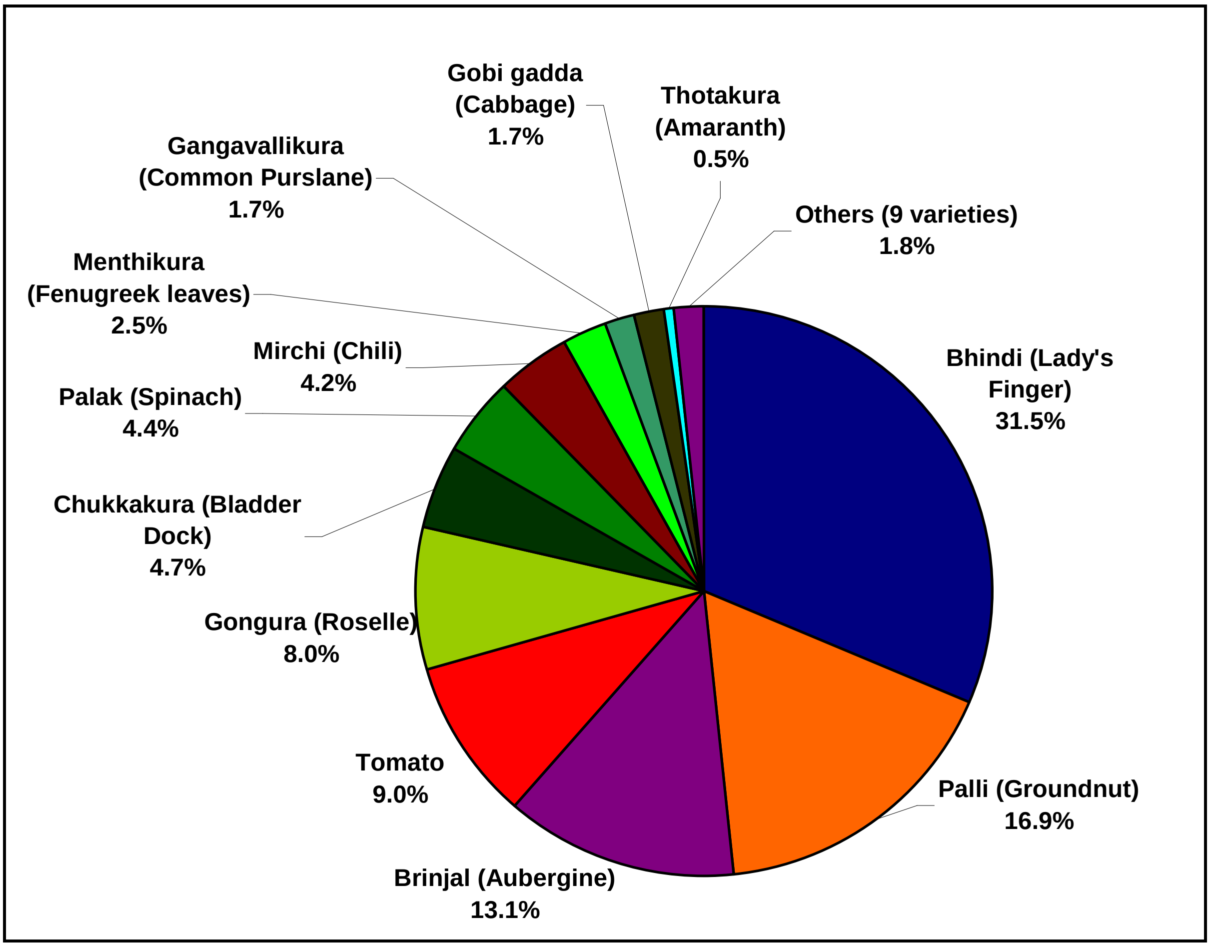

Figure 36: Share of vegetables in groundwater-irrigated gardens mapping September/October 2008

Evidently, diversity was high in both systems (ranging in the upper half of the maximum possible diversity in the *Shannon-Index* and in the upper third in the *Simpson's Index of Diversity*). Even in the smallest gardens of around one fourth acre, up to 13 varieties were found due to crop rotation, intercropping, which was common in the groundwater-irrigated gardens (8.8% of the total area), and the custom to grow vegetables for self-consumption or for seed production between the plots. The area of barren plots was not significantly different: 14.1% in groundwater-irrigated sampling frames compared with 12.3% in those where wastewater was used for irrigation which can be interpreted as a similarly high dynamic crop rotation (i. e. the cycle of field preparation, sowing and harvesting) in both systems. Intercropping was not common where wastewater was used; farmers interviewed stated that the leafy vegetables needed different inputs, were planted very densely in small plots and could be damaged if others with different harvesting patterns were in between. Therefore, intercropping was not regarded as practical for intensive cultivation of leafy vegetables.

4.2 Interview Outcomes

To process the raw data derived from the interviews, methods of content analysis were used (MAYRING 2007). Consequently the information needed to be concentrated and categorised according to the homegarden model introduced in Chapter 3.1 (Figure 11). Herein, the decision modules, in this case the farming groups, are in the centre; thus the answers were categorised and analysed according to the research questions. In this section, the socioeconomic information is displayed at first and then followed by the information about adaptation, decision making and the acquisition of agricultural knowledge.

4.2.1 Who are the Farmers?

Of the 30 respondents, according to the distribution of the gardens, 12 were interviewed in Peerzadigudda, 11 in Parvatapuram and 7 in Kachivani Singaram. On average 4.8 persons were working on 1 acre of land cultivated with vegetables. The basic population can thus be extrapolated to around 265 persons working in the field of vegetable cultivation in the three villages Peerzadigudda, Parvatapuram and Kachivani Singaram. The average age was 37.2 years, which can only be a guess since five respondents estimated their age. Twenty respondents (66.7%) never attended school (Figure 37), compared with an official literacy rate of 60.47% in Andhra Pradesh[28]. Among the remaining 10 who attended school, 8 were below 30 years old which could be an indicator for improving school enrolment rates. Twenty-one interviewees (70%) were male (cf. Chapter 3.2.3). It turned out to be difficult to enquire about caste and religious affiliation, therefore no reliable numbers are available from the interviews; many farmers were Muslims and those who were Hindus belonged mainly to *backward castes* and *scheduled castes*[29]. In the IWMI project, it was found that 58% of the farmers in the periurban zone were from *backward castes* (IWMI 2008, p. 12).

The finding "*At present, the barter and sale of vegetables in the wastewater-irrigated urban and periurban areas is controlled by women"* (BUECHLER 2004, p. 29) cannot be confirmed with the data gathered in 2008. There was no indication from the interviews that the farmers and vendors were mainly women, but families (86.7% of the participants) or groups of friends, and tasks were not gender specific ("*everybody does everything*"). However, the male household head was frequently responsible for the marketing and the women could be

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[28] Andhra Pradesh Directorate of Economics and Statistics, Census 2001

[29] The castes are listed in the Indian Constitution for positive discrimination of disadvantaged groups in the very hierarchic system. There are four main classifications: "Other Castes" (OC, the higher castes), "Backward Castes" (BC, low castes), "Scheduled Castes" (SC, Dalits) and "Scheduled Tribes" (ST or Adivasi), compare: Homepage Suedasien-Info

observed more often in the field since men sometimes had other income sources such as cutting fodder grass (30% of the interviewees), or, in some cases, were responsible for the sale of the vegetables.

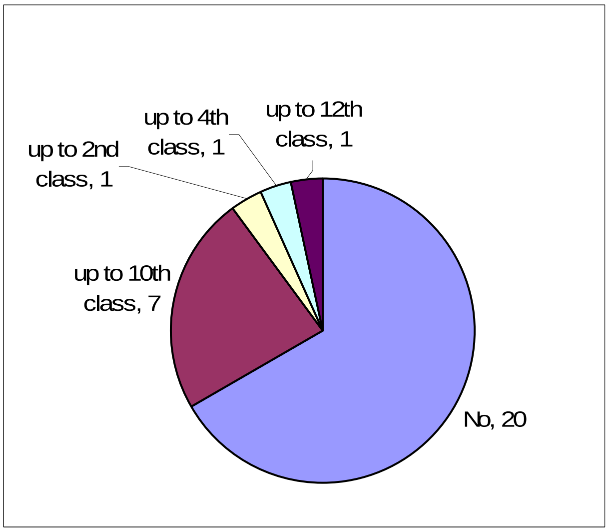


Figure 37: School attendance among participants.

Figure 38: Woman weeding a vegetable plot, October 2008. Image by J. Jacobi

4.2.2 Land Tenure, Migration and Working Situation

The farming groups interviewed consisted on average of 3.2 persons tending 0.93 acres. Only 13.3% (4 respondents) were landowners, the others leased the land, 70% (21 respondents) without any reliable leasing condition, paying the monthly rent in advance. 23.3% (7 respondents) reported to be unsure of being allowed to cultivate their land in the next year or even the next month. A landowner's statement in Kachivani Singaram was indicative for the abundant growth of the city: *"Daily, somebody comes and asks me to sell the land. One acre is already worth 15 million rupees; therefore I will work until I am too old and then sell the land for construction purposes since I don't have a successor".*

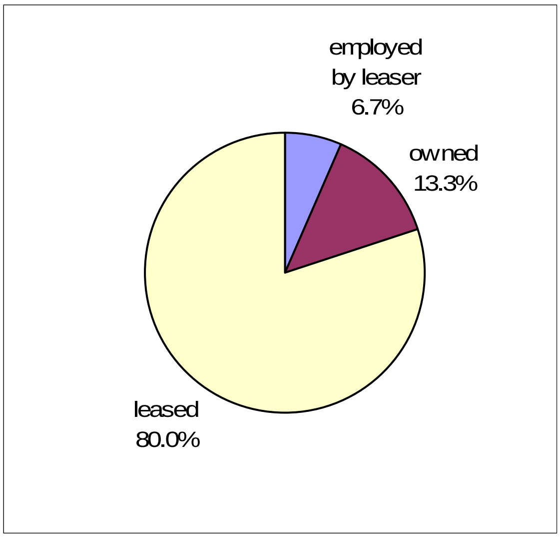


Figure 39: Landownership in the research area

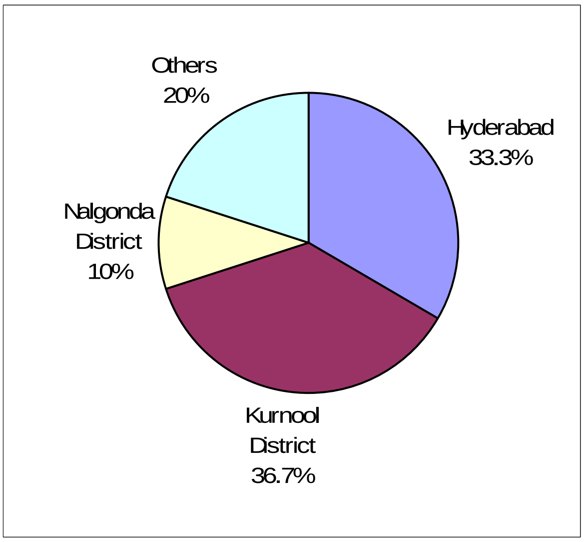


Figure 40: Origin of the participants

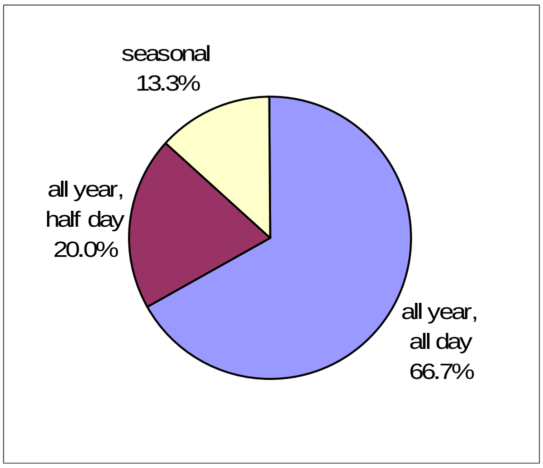
Only one third (10 respondents) were native of the district of Hyderabad, the majority (20 respondents) migrated to the periurban fringes (Figure 40). Fourteen respondents came from the neighbouring districts *Kurnool* and *Nalgonda,* whereas the origin of the remaining 6 with a migration background is unclear. Over 16.0% (5 respondents) mentioned as *push factor* for migration the lack of rain, which rendered wastewater availability a pull factor to periurban Hyderabad. Ten interviewees said that they came primarily in search of work. KRISHNAGOPAL & SIMMONS (2007, p. 9) quoted that:

> *"Driving forces for rapid urbanisation are the expanding of the service IT sector (…) and migration of families from rainfed rural Andhra Pradesh (…) [which] has resulted in a concomitant rise in land prices. (…) this has resulted in a rapid decline in land available for urban agriculture and a concomitant increase in the demand for food products".*

It is difficult to estimate the average income per person: Earnings were subject to intense fluctuations like inputs (pesticides, seeds and fertilizer were purchased on demand, e. g. in case of infection), natural hazards (10% reported severe losses the month before the interviews took place due to heavy rains, others reported fluctuations in their income) and seasonality. After taking into account the income, leasing and input expenditures for the foregoing month, six respondents showed a deficit (INR 1163 on average), resulting in an average monthly income of INR 1617.2[30] per person altogether. For comparison, a female teacher in a secondary school in Parvatapuram reported to earn INR 3000/month (source:

[30] € 24.7, currency rate march 2009

personal communication). It is important to note that this can be completely different during another month. Moreover, not all labourers earned money, notably children worked for board and lodging.



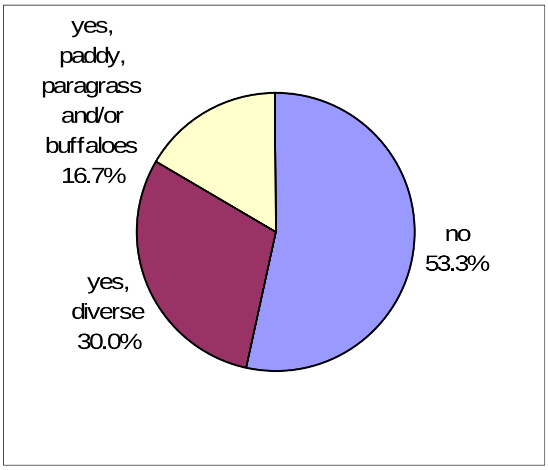


Figure 41: Working situation of the participants, Figure 42: Household income sources besides vegetables

BUECHLER & DEVI (2002, p. 15) stated similar findings that are supported by this study:

> "*Landowners belong to a multiplicity of caste groups. The average landholding is 0.4 ha of irrigated land. In the Indian context, these farmers are therefore categorised as small farmers (…) the casual labourers are male or female migrants from a drought-prone district. Some were squatters on the banks of the Musi and were relocated to an urban resettlement area. Most are BCs*".

It was also stated that labourers were usually employed all the year with a salary of around € 33/month (BUECHLER & Devi 2002, p. 15). This is close to the threshold of extreme poverty as regarded by the UN[31].

4.2.3 Reasons for Cultivating a Broad Diversity of Vegetables

As reasons for cultivating a broad diversity of vegetables, 83.3% (25 respondents) of the participants of the study mentioned the market. Several aspects of the market played a role: Statements such as "*more varieties mean more customers and therefore more money*" indicated a diversified demand, besides, the need to react to fluctuation in prices was also mentioned (cf. REYES-GARCIA et al. 2008, p. 4). Also the practise of house to house sales

[31] Cf. Millennium Development Goal no. 1: "Halve, between 1990 and 2015 the proportion of people whose income is less than 1 Dollar per day"

required a broad range of products. Five respondents (16.7%) said that diversity rendered them less vulnerable to pest infections and diseases in the crops and yield losses. All agreed that a broad diversity was desirable and the three respondents with the lowest diversity (only six varieties) mentioned reasons like their old age and lack of labour for not cultivating more different crops. Forty-one varieties of vegetables were mentioned during the interviews to answer the question "*please name the vegetables that you cultivate"* (Figure 43). This and the seasonal calendars give a broader impression than the mapping since the whole year was reflected. The frequency of certain vegetables may depend on the seasonality while the high amount of leafy vegetables is linked to insecure land tenure and wastewater irrigation (cf. Chapter 5.1).

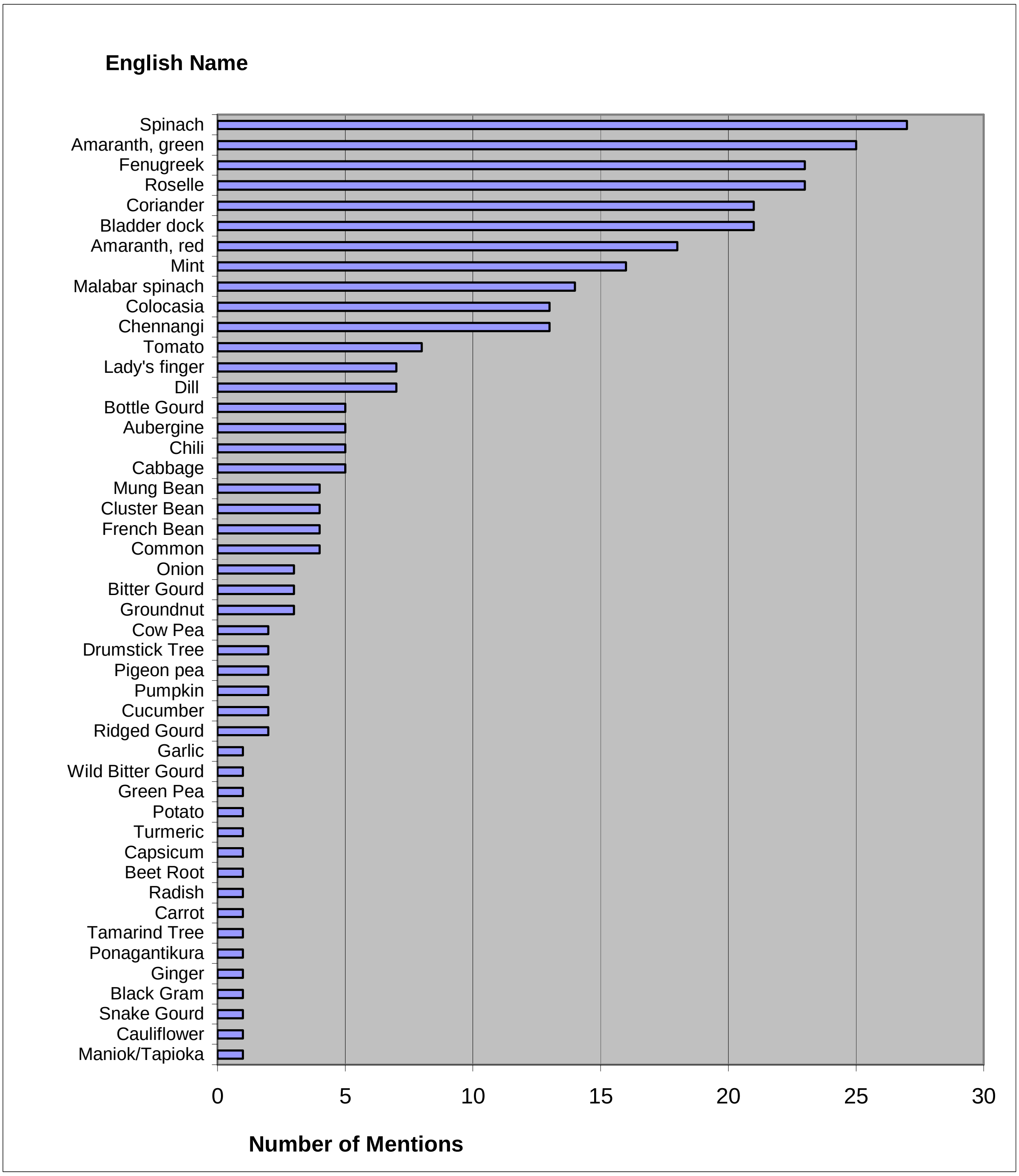


Figure 43: Vegetables cultivated in the research area, as listed by the interviewees

The five predominant crops were different in the mapping results. Fenugreek and coriander ranked 3rd and 5th respectively were cultivated on only on 0.9% and 2.6% of the area sampled. This could be due to the season, but also due to increasing fertilizer prices: Both were reported to be important winter crops, but also to require high expenditures for seeds.

For the question if the number of varieties was influenced by factors such as gender, age or experience of the decision maker, the *Shannon-Index* could not be used for the correlations since the individual gardens were not sampled exactly according to the interviews; therefore the number of varieties mentioned by the interviewees was used. A positive, statistically tested correlation was found between the number of varieties and the **size of the cultivated area** (r = 0.49), a stronger positive correlation with the **years of experience in vegetable farming** (r = 0.63) and weakly, but also with years of **school attendance** (r = 0.37) and **agricultural knowledge** (r = 0.38), which was categorised in three classes (cf. Chapter 5.2 and statistics Annexe III). Not significantly positive was the correlation between the age of the deciding person and the number of varieties (r = 0.34), the gender of the deciding person was slightly, but not significantly negatively linked to the number of varieties in gardens where women decided (r = - 0.18). Other assumed parameters influencing agricultural biodiversity could not be correlated in this study. To verify this, a broader data acquisition would be necessary. **To sum up, experience, agricultural knowledge, education and the available land influenced the number of cultivated varieties.** In a study in Peru, it was found that ethnicity, distance to the markets, tourism, socio-economic structures of the households, garden characteristics and planting material influenced crop diversity (REYES-GARCIA et al. 2008, p. 5). It is therefore imaginable that the influencing factors vary from region to region.

4.2.4 Factors Influencing Decision Making

The questions "*What do you consider when you want to plant something*" or "*How do you decide what to cultivate*" (cf. Annexe II) lead to intense explanations and discussions. The essence of the answers was classified into categories as listed in Figure 44:

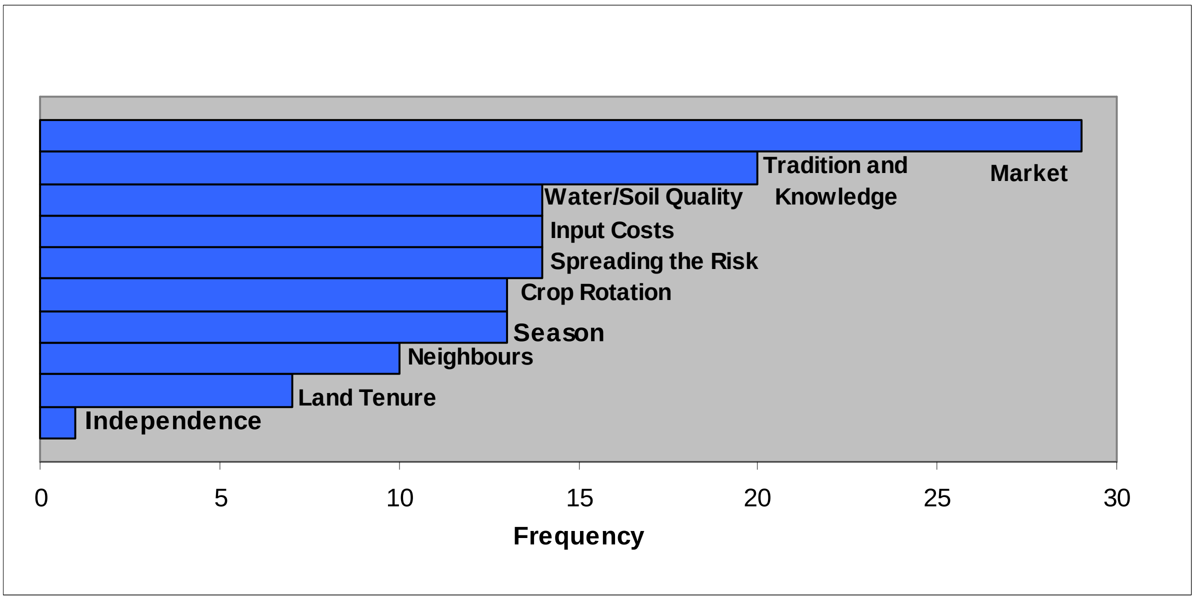


Figure 44: Importance of influencing factors, according to the number of mentions (N=30, no ranking)

In Figure 44, the parameters are abbreviated for easier analysis. These categories are interpretations of the answers: All that had to do with market demand and -prices was classified as the first (and most important) category. Statements like *“I know only how to grow these vegetables”* or “*We have been growing these since childhood”* formed the category *tradition and knowledge*; *independence* is a category derived from statements like *“I don’t want to work for others, by renting this land I can be independent and can keep house only for me and my family”*. More exact description and interpretation of these categories follows in Chapter 5.

After mentioning and discussing the factors, the interviewees were asked to state the importance in a ranking. The different categories were then given numbers from 1 to 10 (categories not mentioned where given 0) according to their importance to calculate the ranking (COTTON 1996, p. 98; MARTIN 2004, pp. 132-125; cf. ATTESLANDER 2008, pp. 218-226). However, this can only be an impression due to fluctuations in the prevalence of a certain factor and the fact that ranking tries to put human decisions into units; displaying social data in numbers can be problematic (ATTESLANDER 2008, pp. 12-13).

Table 4: Ranking of influencing factors with number according to importance (10=most important, 1= least important, N=30)

Preference Ranking		
Decision Influencing Factors what to cultivate	**Total Score**	**Ranking**
Market (price and demand)	259	1
Tradition and agricultural knowledge	147	2
Input (costs for seeds, fertilizer, pesticides, labour)	112	3
Crop rotation	104	4
Spreading the risk	97	5
Water and soil quality	89	6
What neighbours cultivate	80	7
Land tenure ("to be able to pay the monthly rent")	54	8
Season	49	9
Independence	5	10

The ranking and Figure 44 (according to the number of mentions of the factors) give almost the same order of importance, but the category *water quality* was mentioned more often by the participants than put in a high place in the ranking. Possibly, the awareness for what the neighbours cultivated in their plots was higher because all neighbours had to deal with similar water conditions. The marketing factor was uncontested on the first rank, followed by tradition and agricultural knowledge.

4.2.5 Acquisition of Agricultural Knowledge

Since sustainable agriculture and land management are knowledge intensive and considerable efforts are put into farmers' education (e. g. by the Indian government through agricultural extension services[32]), it is important to know the knowledge sources if the aim is to reach farmers with education programmes. At first, the participants were asked how they acquired their agricultural knowledge. Over 53.0% mentioned their family (16 respondents), 43.3% friends and neighbours, only 6.7% learnt from the landowner they were working for. Nobody mentioned external sources like development programmes or extension services (Figure 45).

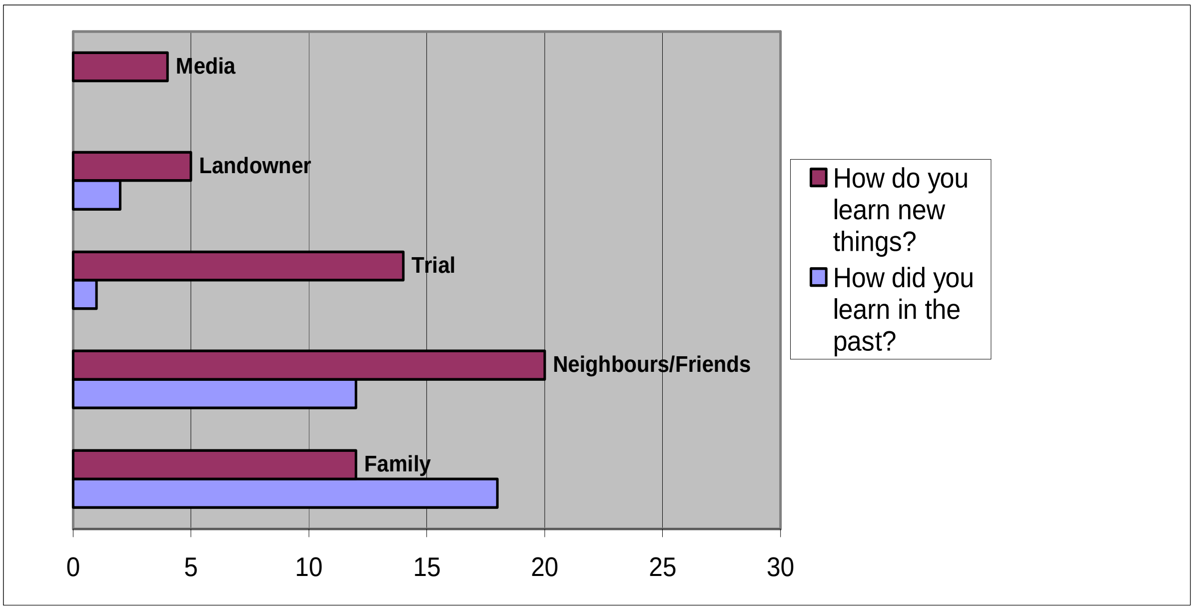


Figure 45: Knowledge sources, according to number of mentions, multiple answers possible (N=30)

The information sources for further education ("*How do you learn new things?*", cf. Annexe II) give a different impression: The family moved to the second rank, most likely due to the shift from cultivating cereals to vegetables (17 participants in the last 10 years). Landowners played a more important role in knowledge transfer and education programmes were mentioned such as information from telecasts and newspapers. However, they were on the last rank which can be interpreted as a clear need for more focusing on smallholder farmers with media and agricultural extension services. Internal passing on of knowledge was very strong (cf. Chapter 5.1.3), but so far, external sources of information played only a minor role.

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[32] The Agricultural Department of Andhra Pradesh (http://agri.ap.nic.in/) for instance has the task to provide agricultural extension services. For more information: http://agri.ap.nic.in/extension.html

Table 5: Ranking of knowledge sources with number according to importance (5=most important, 1= least important, N=30)

Ranking (referring to "How do you learn new things?")		
Source	**Total Score**	**Ranking**
Neighbours/Friends	92	1
Family	61	2
Trial	53	3
Landowner	20	4
Media (Telecasts, Newspapers, Agricultural Extension Services...)	17	5

4.2.6 Perception of the Irrigation Water Quality

From the interviewed farmers, 80% used wastewater for irrigation, either from the Musi River or from the sedimentation lake *Nallah Cheruvu* (Telugu for "Black Lake"). This represents approximately the groundwater-wastewater ratio of 82.9% of the entire area under wastewater irrigation and 17.1% under groundwater irrigation. BUECHLER et al. (2006, p. 245) stated: *"Musi water is used by approximately 250 households for agriculture on a total of about 100 ha of land in the urban area along the Musi River"*. This could be exceeded in the periurban area since in the three research villages alone, approximately 216 persons were cultivating vegetables with wastewater irrigation, if rice and fodder grass cultivation is added to the calculation (cf. Chapter 4.2.1). Figure 46 gives an impression of the extent of wastewater use (brown colour) in agriculture along the Musi River.

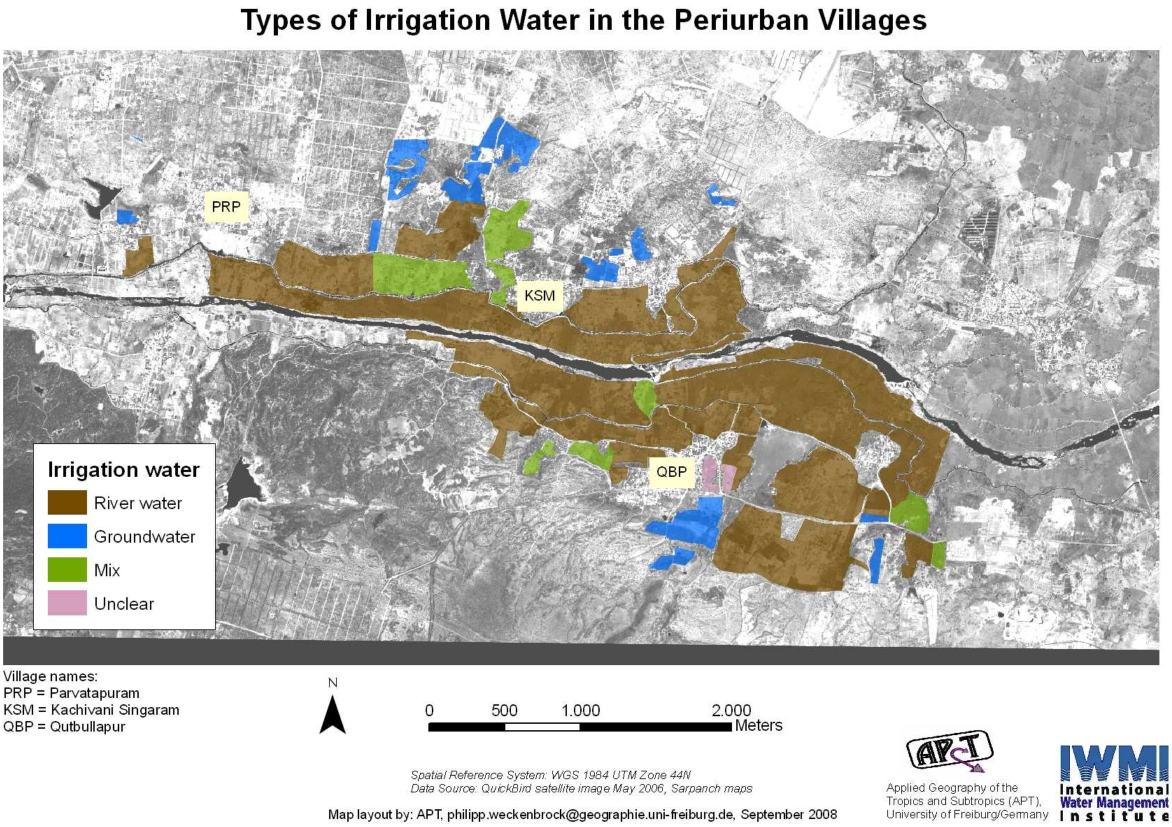

Figure 46: The map shows the great extent of wastewater irrigation (brown colour) in the research area (IWMI 2008, p. 19)

The question *"Is the water good or bad for vegetable cultivation? What do you like/don't like about it?* (cf. Annexe II) was answered by 86.7% (26 respondents) in a positive way. Sixty percent (18 respondents) noted a fertilizing effect and 40% (12 respondents) indicated a particularly good effect on leafy vegetables (sometimes it was mentioned that wastewater was good for the plants in spite of being polluted and therefore harmful to humans). Only one respondent stated: "*The groundwater is salty and gives me pain in the back. It is not good for the vegetables, they don't grow nicely. Musi water is even worse; it makes the vegetables spoil faster".* One respondent was neutral, another one regretted not being able to use wastewater: "*Those who have it get more yield".* According to BUECHLER (2004, p. 32), the amount of wastewater used for irrigation and other livelihood activities along the Musi River is the same as the amount of wastewater generated in the city of Hyderabad.

 

Figure 47: Black water in irrigation canal in Peerzadigudda, October 2008

Figure 48: Field preparation in Parvatapuram, October 2008, Images by J. Jacobi

5 Interpretation of the Findings

In the following the homegarden model will be applied to the data collected in the fieldwork and interviews; the findings are discussed in the light of current discourses and development research. The parameters that influence biodiversity are displayed according to the framework introduced in Chapter 3.1, with special emphasis placed on local knowledge and wastewater/groundwater irrigation and their role for livelihoods.

5.1 Decision making in the Livelihood Context

Within the household system, it is the entitlements and assets that determine activities and outputs. Supporting and non-supporting superordinate structures such as society, social networks and NGOs influence all decisions at the household level. Within this framework, the homegarden model allows organising and interpreting the main parameters mentioned by respondents and tying them to the SLA.

5.1.1 Supporting and Non-Supporting Structures

The homegarden framework provides for a number of influencing structures including household networks, markets, infrastructure, legal security, loans, local networks, research, government, NGOs, educational systems and national and international development agencies (DRESCHER et al. 2006, p. 328).

As this study focuses on the household level (micro level), observations about superordinate structures derive exclusively from respondent statements. The farmers suggested that **governmental programmes** supplied insufficient support and that **social networks** among the different farming groups were de facto non-existent; "*everybody works for himself*" and "*we cannot trust others*" were statements made in the interviews. With 86.7% or 26 respondents farming with their relatives, the core of the system was clearly the **household network**. Other influencing structures such as supporting projects enhancing UPA, institutional support through wastewater treatment and also non-supporting city planning activities are listed in a case study on the value chain of agriculture along the Musi River by KRISHNAGOPAL & SIMMONS (2007, p. 22).

Market Situation

The dominant factor in more than 50% of the interviews was the market, and all respondents mentioned market demand and market prices as important in determining what they grow in their gardens. This implies a demand for a broad range of vegetables due to their use in traditional dishes. Moreover, a high diversity enables farmers to react to variations in demand. Even the middlemen prefer to purchase different varieties from each farmer to buying large amounts of one vegetable, one respondent said. KRISHNAGOPAL & SIMMONS (2007, p. 11) come to a similar conclusion:

> "*The high urban demand for perishable leafy vegetables (…) and limited storage capacity particularly during February to September is one of the key driver's behind the expansion of wastewater-irrigated vegetable production in peri-urban Peerzadiguda and Parvatapurum, Rangareddy district [sic] ".*

All interviewees used part of their yield to feed their families, so that cultivation was important both as a source of income and as a source of food (cf. DRESCHER et al. 2006). It is interesting to note that REYES-GARCIA et al. (2008, p. 12) found a positive association between agricultural biodiversity and production for self-consumption in a study in the Amazon region, which suggests that farmers producing crops for use in their own household make an important contribution to maintaining crop diversity.

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5.1.2 Entitlements

The homegarden model defines entitlements as the rights to "*quality and quantity of resources*" (see Figure 11). Transferred to periurban vegetable production this means reliable access to suitable land, water and other necessary inputs.

Land Tenure

Cropping patterns strongly depend on who owns the land. Respondents frequently mentioned ownership (ranked 2nd), but in relation to other factors it dropped to 8th. Those who did not know whether their land would be available again the next month cultivated leafy vegetables that could be harvested every 15 to 30 days to sustain a constant income source. Those who owned the land they worked on were able to cultivate vegetables that need several months before giving yield but possibly provide a higher income. Generally, a landowner can plan in the long term, experiment with composting and plant fruit trees, none of which makes sense for farmers renting land on a monthly basis. For example, plants like drumstick (*Moringa oleifera*) or tamarind trees (*Tamarindus indica*) were only found in gardens cultivated by the owner or rented on a yearly basis. Fast-growing (non-lignifying) fruit trees like papaya and banana, too, were rarely found in wastewater-irrigated gardens rented on a monthly basis. The interviews addressed the influence of land tenure on agricultural biodiversity by asking farmers whether they would grow the same crops if they owned the land which they were cultivating. Among the 24 respondents who leased the land, nine expressed the wish to cultivate different crops and said they would do this if the land belonged to them. Reasons mentioned for a different choice of crops were less work, including no need for daily selling, a higher income and "*fewer pests*"; seven respondents expressed the wish to cultivate non-leafy vegetables bud did not say why. The remaining 15 who said they would not change cropping patterns if they owned the land named the guaranteed daily income, the water and soil quality ("*this land and water is only suitable for leafy vegetables*") and the risks arising from higher investments associated with other crops as reasons. The only respondent cultivating fruit-bearing vegetables with wastewater from the Musi River said that they required less work and specifically mentioned tomatoes. Two statements were very similar: "We can never afford to become landowners; therefore we cannot imagine what we would do". This seems to indicate how important land issues are, considering that farmers cannot or do not want to imagine what owning land would be like.

DANSO & MOUSTIER (2006, pp. 177–78) analysed similar cropping systems in Brazzaville, Kongo, and Yaoundé, Cameroon. They argue that "*this reflects the necessary intensification per unit of land in a context of high pressure on land*" (ibid.). SMALE (2007, p. 7) has raised the issue of conservation, saying that the need for short-term planning in poor farming societies was difficult to reconcile with conservation interests which need long-term thinking.

In a consultancy paper the Department for International Development speaks of land as "*a key factor in poverty reduction*" (DFID 2002, p. 5). The authors argue that *"if people have uncertain rights to their land, they have little incentive to invest in or conserve it*" (ibid., p. 10). Ensuring land rights is therefore crucial for sustainable agriculture as well as for sustainable livelihoods. The Indian government, however, met the demands of major players rather than small farmers when it facilitated land acquisition by setting up Special Economic Zones[33] where economic laws are more liberal than elsewhere in India. This law was entitled the "*biggest land grab movement in modern India*"[34].

Distance from the city

Access to markets is another important factor in this category. Producing at a short distance to the market is an advantage that most urban and periurban farmers share. Consumers require a steady supply of fresh leafy vegetables. Quick transport of the perishable leaves is essential; and indeed the share of leafy vegetables in cultivation patterns decreased as the distance from the city increased in the research area. Non-leafy vegetables are usually more durable and statements made by seed traders indicate that the entire production of leafy vegetables consumed in Hyderabad comes from a perimeter of 60 km (personal communication). As mentioned above, 30-80% of the urban vegetable demand can be met with produce grown within the city or in the periurban areas of Hyderabad. Respondents sold their wares in the nearest markets, most of the vegetables from Peerzadigudda and Parvatapuram being sold in Uppal, the part of Hyderabad closest to these areas. KRISHNAGOPAL & SIMMONS (2007, p. 14) found that usually the vegetables were washed and stored after harvesting and sold to a wholesaler early the following morning.

5.1.3 Assets

An asset, according to the SL framework, is wealth in the sense of social, economic and environmental capital, which individuals or households use to ensure their livelihoods. Originally, in the SL framework, assets are subdivided into human, social, natural, physical and financial capital. For the purpose of this study, the assets were defined on the basis of respondent statements on factors important for decision making and arranged according to the homegarden model (see fig. 11), as follows:

Primary assets can be resources such as land, water, seeds, knowledge, labour and time.

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[33] The law was passed in 2005 and has been controversially discussed since many farmers were expropriated. More information on SEZ: http://www.sezindia.nic.in/

[34] BBC News, South Asia, 2. 10. 2006. http://news.bbc.co.uk/2/hi/south_asia/5391058.stm

Secondary assets can be animal husbandry, fertilizers, pesticides, herbicides, tools, stores, buildings and other monetary values.

Agricultural Knowledge as Sociocultural Capital

Although 27 interviewees (90%) came from a farming background, many had shifted from cultivating other field crops like rice or fodder grass in the last 10 years (56.7%, 17 respondents). The level of traditional agricultural knowledge concerning vegetable cultivation (cf. Chapter 5.2) can therefore be estimated as lower than in traditional farming systems. New methods of cultivating leafy vegetables were learned from friends and neighbours *(farmer to farmer)*.

Only four respondents mentioned the Department of Agriculture (DOA)[35] as helpful in knowledge acquisition. The role of the DOA is to provide farmers with agricultural extension services such as transferring technical knowledge, introducing high-yield varieties and improving the farmers' skills through training. Agricultural extension services were only known by two persons (6.7%), which confirms the statement made by KRISHNAGOPAL & SIMMONS (2007, p. 19), who say that the DOA focuses on rural large-scale grain producers and that "*urban and periurban agriculture currently falls outside the mandate of the DOA"*. Municipal authorities rarely include urban farmers in their considerations and therefore tend not to provide any extension services to them (BUECHLER et al. 2006, p. 255).

The following experience recounted by one respondent indicates that the implementation of positive measures can be less than ideal:

> *"I read in the newspaper that the DOA now provides green manure seeds for free. Thus, I walked to the next village, where I was told to go to another office in another village, where I was told to go to the head office in the city. That is 10 km away. I am on foot and 94 years old, what can I do? So I walked there and was told to come back in two or three weeks. It took me a whole day to go there and back, a day I could not work in the fields. It was impossible for me to get these seeds. It is always like that."*

As mentioned in Chapter 4.2.5, the passing on of agricultural knowledge among the farmers was very strong. For external knowledge sources it is therefore not necessary to reach each farmer but only a few key persons who are likely to spread the new information. Field schools with an equally distributed selection of smallholders could result in a snowball effect without costly projects for all farmers. However, material such as green manure seeds should also

[35] More information is provides at the DOA website: http://agricoop.nic.in/

be provided and distributed in a reasonable way to avoid situations like the one described in the statement above.

Crop Rotation as an Example for Traditional Agricultural Knowledge

The knowledge about cultivation practices such as crop rotation (cultivating a different plant after harvesting another in one field) may be expected to be an indicator for agricultural knowledge. Nineteen farmers (63.3%) said that they practise crop rotation. Twelve participants (40%) did not specify ("all crops need rotation), but the remaining seven (23.3%) described specific crop rotation patterns such as "*after Palak, no Thotakura can be planted*" or "*I have good experiences with Gobi after Brinjal".* Some had a much differentiated knowledge about crop rotation, green manure and planted legumes which can contribute to higher yields[36]. A spatial circular knowledge gradient could be followed among their neighbours concerning crop rotation, maintaining soil fertility by using compost and manure, and seed production: In one instance an interviewee showed extensive knowledge of which vegetable to cultivate after which other; his immediate neighbours stated that crop rotation was necessary in order to maintain high yields but did not specify the rotation patterns. Farmers whose fields lay at some distance from the source of knowledge did not mention any special cultivation patterns or crop rotation. No respondent however seemed to have such profound knowledge as the key informant, who benefited from his 60 years' experience in organic farming. He was, for instance, the only person who mentioned cultivating sunn hemp (*Crotalaria juncea*) as green manure to sustain soil fertility. Again, there is a clear need for information to be spread and a better distribution of knowledge and experience referring to the specific conditions encountered in this region and in this branch of agriculture.

Traditions

Only few respondents specifically mentioned tradition as an important factor; possibly the awareness of its role for decision making is not very strong. Since the majority of the sample derived from farming families and since a total of seventeen people (56.7%) made statements categorised as "tradition" in the content analysis, however, this is a factor that may be considered as important for crop diversity. South Indian food traditions certainly play a crucial role: The very popular *thali* is a combination of rice and various vegetable curries for which often eight to ten different vegetable dishes with legumes are arranged in small bowls around the rice. This type of food naturally gives rise to a demand for diverse vegetables and pulses.

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[36] A study in Benin showed, for instance, that about 100.000 farmers increased yields by intercropping legumes with corn. Velvet bean (*Mucuna pruriens var. utilis)* was used which inhibits the growth of weeds and increases soil fertility through N fixation (SHIVA 2000, p. 134).

"*What my neighbour grows plays a role for my decisions what to cultivate"* or similar statements were made by ten participants (33.3%) in the areas where wastewater was used and where the gardens were small and tightly packed. Neighbours inspired each other in a process of mutual exchange of knowledge, but stepping out of line was also seen as a risk: *"If I plant something other than my neighbours, someone would take the yield away. Pigs and monkeys come and eat my vegetables".*

Customers' traditions influence agricultural biodiversity through demand: A survey in the municipality of Serilingampally showed that 100% of the customers who were interviewed purchased vegetables, with 80% saying that they usually buy five or more varieties. More than thirty vegetable varieties were reported to be available in the market of Serilingampally (IWMI/RUAF 2007, p. 22).

Natural Capital: Water and Soil

The water quality of the Musi River water was analysed by IWMI from 2005 to 2007. It was found that "*with increasing distance from the city, total nitrogen and biological oxygen demand (BOD) levels in the river water decreased significantly while electrical conductivity (EC) increased*" (IWMI 2008, p. 24). The interpretation is that nitrogen (ammonia, NH_3) evaporates and therefore total nirogen decreases. Conductivity increases are probably due to water loss and effluents from fields cultivated with fodder grass and vegetables using chemical fertilizers (ibid.).

The water was tested for E. coli, nematode and hookworm eggs, biochemical oxygen demand, electrical conductivity and total nitrogen. According to the WHO *Guidelines for the Safe Use of Wastewater, Excreta and Greywater* (WHO 2006), the water taken from the sampling point at Peerzadigudda cannot be classified as suitable for irrigation (cf. IWMI 2008, pp. 22-25).

In terms of soil quality, the concentration of heavy metals in periurban soils was tested by IWMI in 2007. In the 28 plots sampled, lead, zinc (with the exception of four plots) and cadmium (with the exception of three plots) were below the EU maximum permissible levels. Moreover, the high soil pH level inhibits heavy metal absorption in plants (ibid., p. 26).

Irrigation with Musi water is categorized as both positive – in terms of exchangeable potassium, available phosphorus, nitrogen – and negative in terms of the effects in terms of electrical conductivity (yield reductions to be expected due to high conductivity) and excess nitrogen (ibid., p. 30).

The statements of seventeen farmers (56.6%) and the evidence of the mapping (showing leafy vegetables on wastewater-irrigated fields and fruit-bearing vegetables on groundwater-irrigated fields) suggest that leafy vegetables grow well with wastewater irrigation, which has a fertilizing effect. With other, non-leafy vegetables, wastewater irrigation did not yield a good fruit quality and could even damage the plants. This view is supported by Professor Christian Richter (University of Kassel, Germany) who says that nitrogen is advantageous and necessary for high yields but of disadvantage where the taste of fruits and vegetables is concerned because it inhibits the accumulation of sugar and taste-influencing organic acids in plants (personal communication). Instead, amino acids are accumulated which do not contribute to a good taste. Furthermore, a surplus of nitrogen causes dark-green, spongy leaves, since cellulose is reduced in favour of amino acid and protein synthesis (cf. RICHTER 2005, p. 209; AYERS et al. 1985, Chapter "Excess Nitrogen"). For the same reason, rice was less often cultivated near the city where the water is more polluted and was replaced by fodder grass, as can be observed in the satellite image (IWMI 2008, p. 16; also cf. Chapter 6.1). Rice cultivated with wastewater has very poor post-cooking storage rates and changes colour within two hours (SIMMONS 2008, personal communication).

In relation to health issues, according to BUECHLER & DEVI (2002, p. 16), the perception of the influence of wastewater is mixed: There is a difference in exposure to wastewater between urban/periurban farmers and rural farmers. In the periurban fringes, rice is less often cultivated than in rural areas and people therefore spend less time standing in the water. Whereas some farmers said they had no health problems associated with the water, others reported periodic rashes and skin irritation as well as fevers at least once a month and countless insect bites (BUECHLER & DEVI 2002, p. 16). In the documentation video *Making a Living along the* Musi River (BUECHLER et al. 2003), interviewees link joint pains to wastewater; research however has shown that skeletal fluorosis is caused by a high uptake of fluoride in the drinking water from wells. South India is especially at risk concerning groundwater fluoride contamination (JOHNSON 2008). Groundwater exploitation leads to a drawdown of the aquifer with modified rock alteration delivering geogenic fluoride to the groundwater[37]. Bone char filters are a viable option for fluoride removal (ibid.), but the cultural context has to be considered (cow/pig bones not allowed in Hinduism/Islam). It is generally possible that other contaminants penetrate the groundwater body from untreated wastewater on the surface. Thus, some problems that are attributed to wastewater have causes that are unrelated to wastewater.

It can be concluded that the use of wastewater has both positive and negative effects on agriculture. While it obviates the use of high amounts of fertilizer, thus opening up a possibility of reducing expenditures, it does entail health risks which, however, could be mitigated by washing and cooking food crops like vegetables (cf. FATTAL et al. 2004). In the present survey, the perception of the use of wastewater in agriculture was mostly positive (cf. Chapter 5.3). However, though vegetable farmers were aware of the advantages that

[37] EAWAG Project „ Water resource Quality". More information: EAWAG homepage, ETH Zürich

wastewater can provide, they still used high amounts of chemical fertilizers. This indicates that there is some potential for saving money by using only those specific fertilizers that are not supplied by the wastewater.

Financial Capital

Most of the agricultural research area was cultivated with fodder grass (56% in the periurban zone mapped for the IWMI project) which can bring more income than vegetables (up to € 2812/ha/year from fodder grass compares with € 833/ha/year from vegetables, BUECHLER & DEVI 2002, p. 16). Participants affirmed that "*cutting fodder grass requires more energy than growing vegetables"* and the alternative of self-consumption does not exist (at least if the household does not own a buffalo). Five participants (16.7%) had shifted for similar reasons from harvesting and selling fodder grass to vegetable production. It seems that there is no discrimination in the salary paid to men and women, at least not in the fodder grass business (KRISHNAGOPAL & SIMMONS 2007, p. 13). It was found that "*a couple can earn 10.48 to 17.6 US$ together by working for four hours in the field in the morning hours. The afternoons are free to pursue other labour work [sic]. The lease rates are Rs 2000 (44 US$) per month per acre*" (ibid.).

Table 6: Income from agricultural activities with the use of wastewater for irrigation (BUECHLER & DEVI 2002, p. 16)

Activity	Cost of production per hectare (Rs. and €)	Income (Rs. and €)	Average annual income (Rs. and €)
Leafy vegetables (Rs/ha/month)	Rs. 3,750/€ 78 per month	Rs.5,000/€ 104 per month	Rs. 40,000/€ 833 per year
Banana (for 100 plants)	Rs. 7,200/€ 150 per year	Rs. 22,500/€ 470 per year	Rs. 22,500/€ 470 per year
Coconut (for 100 palms)	Rs.7,200/€ 150 per year	Rs. 10,000/€ 208 per year	Rs. 10,000/€ 208 per year
Para grass per ha	Rs. 45,000/€ 937 per year	Rs. 90,000-180,000/€ 1,875-3,750 per year	Rs. 135,000/ € 2,812 per year
Para grass (rent collected Rs/ha/month)	NA	Rs. 2,500/€ 52 per month	Rs. 30,000/€ 625 per year
One milch buffalo	Rs. 500/€ 10.40 per month	Rs. 2,000/€ 42 per month	Rs. 16,000/€ 333 per year

Since the farmers reported a shorter time between sowing and harvesting than the literature (AVRDC 2003; TINDALL 1983), more frequent harvests (possibly related to the nutrients in the wastewater) can be regarded as a clear advantage as compared with groundwater or rainfed agriculture which may result in higher year-round incomes. As stated in Chapter 4.2.2, almost half of the participants had another income source in addition to vegetable cultivation. It was clearly part of the livelihood strategy to diversify income sources, even though most interviewees regarded cultivating vegetables as a reliable source of income. According to BUECHLER et al. (2006, p. 250), rearing buffaloes contributes to the household income because the highly nutritive milk can be consumed by the family members with the surplus sold. If fodder grass is another income source, expenditures for fodder can be saved, too, which makes it profitable to combine vegetable and fodder grass cultivation with the rearing of at least one milch buffalo. It was stated that in general, vegetables provide a secure market since the middle class consumers' demand for fruit and vegetables is growing (YASMEEN 2001, p. 6).

Input costs: Seed Availability and Prices as Indicators

The insecure land tenure situation did not allow the self production of seeds as the participants quoted, because the plants need several months to develop to maturity. Being harvested after two weeks, the time period was too short. This might be one reason why almost all seeds were purchased in the numerous seed shops in and around Hyderabad. Those farmers who showed a broad agricultural knowledge produced some seeds themselves, but this was only a share of 16.7% among the participants. Even though hybrids were not common in leafy vegetables cultivation, besides *Pudina* (*Mentha sp*.), which was distributed as perennial plant among friends, all leafy vegetable seeds were available in the seed shops. Shortages did not appear to be a problem, but the prices influenced cultivation of 12 interviewees (40%). *Menthikura* (*Trigonella foenum-graecum*) and *Kothimiri* (*Coriandrum sativum*) seeds were subject to increasing prices and therefore less cultivated according to them. The information by farmers and shopkeepers that purchased seeds gave better yields than self-cultivated seeds (not hybrids) could not be tested since no comparative data was available. Hybrid seeds were extremely costly[38] and only three farmers reported to buy them regularly for fruit bearing vegetables. The key-informant stated:

[38] For comparison: In October 2008 in Uppal (part of the Hyderabad urban agglomeration), 10 g of tomato hybrid seeds cost INR 280 whereas 0.5 kg of Chukkakura (*Rumex vesicarius*) seeds cost INR 65. Both can be used for a plot of 2 to 8 m.

"As soon as fast growing hybrids are chosen, the need for mineral fertilizer is there. And as soon as the plant grows faster than natural, pests come due to the disturbed equilibrium. Then also the pesticides are necessary".

Self production of seeds was common for cucurbits due to the fact that only one fruit needs to be dried. For leafy vegetables cultivated in a plot of the usual size of 2 to 8 m, 0.5 kg of minuscule seeds was necessary. For *Thotakura* (*Amaranthus tricolor*, green variety) alone, there was a choice of four types of seeds with diverse characteristics like big leaves or strong stems. One designative statement can be correlated with land tenure as well: *"Seeds making takes time – it is cheaper to buy them. It takes at least two months to wait for seeds which implies a loss of 1000 rupees".*

Low and High Input Crops: Requirement of Fertilizer and Pesticides as Indicator

All participants who cultivated leafy as well as fruit bearing vegetables quoted that "*Leaves need less fertilizer*". Particularly less input-requiring plants were: Onion, bottle gourd, taro, Malabar spinach (*"no fertilizer at all"*), mint, coriander, roselle and fenugreek. Amaranth, dill and bladder dock were both reported to need more and less fertilizer. The highest input costs were reported for cabbage which was cultivated on 1.6% of the mapped area.

Pesticides were often applied without any protective clothes and probably without knowledge about their potential health risks. During the mapping, a young girl applied *Methomyl* with bare hands, a highly toxic insecticide prohibited in the European Union because it acts like a hormone in the human body[39] . RAMANJANEEYULU & CHENNAMANENI (2006, p. 1) stated that so far, 203 pesticides were in use in agriculture in India and for Hyderabad, residues were found above the permissible levels in vegetables.

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[39] EU commission decision of 19 September 2007: Concerning the non-inclusion of methomyl in Annex I to Council Directive 91/414/EEC and the withdrawal of authorisations for plant protection products containing that substance. European Union Law (Official Journal of the European Union).

Figure 49: Amaranth seeds and pesticides in a local seed shop near Peerzadigudda. Images by J. Jacobi

The average monthly income of one farming group was around INR 10,950, whereas the average expenditures for seeds, fertilizer and pesticides were with INR 4,738 very high, representing 43.3% of the income. The costs for the rent of the land were INR 1,028 on average, which resulted in a total input costs of more than half of the income. One should be careful with total numbers, since it cannot be assured answers concerning income and expenditures are correct. Fourty-three percent of the participants mentioned a strong increase in fertilizer prices in the last months. This could be the result of the *fertilizer crisis*[40], leading to soaring prices in mineral fertilizer (nitrogen, phosphate and potash) which has been associated with the strong increase of agrofuel cultivation in the last years among other reasons (also cf. Chapter 5.3).

[40] The Guardian, August 12th, 2008: "Soaring fertiliser prices threaten world's poorest farmers". Available at: http://www.guardian.co.uk/environment/2008/aug/12/biofuels.food

Table 7: Demand and supply of N, P and K fertilizer Source: FAO 2008b, p. 20

Asia fertilizer forecast 2007/2008-2011/2012					
	2007/2008	2008/2009	2009/2010 (thousand tonnes)[1]	2010/2011	2011/2012
N supply	72 123	76 317	79 933	85 491	89 850
Total demand	75 255	76 111	77 961	80 413	82 476
Surplus (deficit)	(2 132)	206	1 972	5 078	7 374
P supply	13 882	14 744	15 484	16 185	17 964
Total demand	19 209	19890	20 560	21 168	21 784
Surplus (deficit)	(5 327)	(5 146)	(5 076)	(4 983)	(3 820)
K supply	5 428	5 524	6 226	6 450	6 530
Total demand	14 485	15 138	15 794	16 464	17 073
Surplus (deficit)	(9 057)	(9 614)	(9 568)	(10 014)	(10 543)

[1] Difference between supply potential and consumption; negative signs denotes deficit situation.

As Table 7 indicates, there is a shortage in all three main mineral fertilizers which is supposed to intensify for nitrogen, but not for phosphate and potash. Since fruit and vegetable production increases quickly in South Asia (FAO 2008b, p. 21), this information points to the need of alternative fertilizing methods, also for maintaining soil fertility in the long term as it is practiced in organic agriculture (UNEP-UNCTAD 2008). Agricultural knowledge concerning the nitrogen-fixing effect of legumes, green manure, the use of compost and manure needs to be conserved and combined with modern knowledge of organic agriculture (SHIVA & PANDEY 2006).

Crop diversity was furthermore linked to reduced nitrogen pollution in the surrounding water bodies in a recent study from Lousiana[41].

5.1.4 Activities and Productivity

Activities in the livelihood context are all economic activities like the production of food for both income generation and subsistence. Also migration is a livelihood activity which has been called "*one of poor people's most important livelihood strategies*" (DFID 2002, p. 18).

[41] In the Environment E-view paper, it was shown that in the surroundings of farms with a high crop diversity, less diluted nitrogen was found. Too much nitrate in the water can lead to prolific growth of aquatic algae, which can use up most of a water body's oxygen when they die and are decomposed, creating "dead zones" that cannot support life. More information: www.frontiersinecology.org, published online 18. 2. 2009 in Nature vol. 457

The results or outputs of all these activities are mainly food and income, but also any imaginable contribution to sustainable livelihoods in economic, social and ecological ways.
Results of livelihood activities according to the homegarden model can be species diversity, soil improvement, microclimate, status, social peace, economic power, political power, waste reduction or community empowerment and many more (DRESCHER et al. 2006, p. 328).
Some of these activities which are especially important in this context (derived from the interviews), ideally leading to the achievements listed in the box "*Livelihood outcomes*" in the homegarden model, are highlighted in the following subsections.

Spreading the Risk

Risk mitigation was claimed to be a reason for agricultural biodiversity by 16 participants (53.3%), but during most interviews it was not mentioned first. Therefore it was only ranked 5th, but obviously played a role. The risk of cultivating one or two crops would be too high, so the explanation, if one pest gets out of control, the entire yield can be lost ("*when pests come, not all plants get infected if I have many varieties. Therefore, not the entire yield will be lost*"). Risk was managed by choosing diverse crop combinations (cf. BIROL et al. 2007, p. 35; SHIVA & PANDEY 2006). A broad diversity mitigates vulnerability and can therefore be regarded as a strategy to strengthen resilience (CROMWELL et al. 2001, p. 96). Diversity allows shifting the production, e. g. from fenugreek to more amaranth in case of increasing seed prices for one variety. Another aspect is the possible adaptation to increasing fertilizer prices: Especially in the short-term cropping system with rotations of 2-6 weeks one can easily react by cultivating more low-input vegetables.
Social networks can be another option to mitigate risks by building farmers' associations but a lack of trust was widespread as the statements indicated. Mutual advice was given but actual help was impossible according to the participants.

5.1.5 Livelihood Outcomes

According to the homegarden model, species diversity is among the livelihood outcomes ("*direct and indirect benefits*"). However, in this case, diversity of vegetable varieties led to outcomes like being more resilient to economic and ecological stress factors. Thus, diversity was not an end in its own right but a means to achieve the aim of resilience. Agricultural biodiversity, in the context of this study, can be regarded as an aim or outcome on the macro level, the society level (cf. Chapter 2.4). On the micro level of farmers or households it was a strategy to achieve livelihood outcomes such as income and food security. A broad diversity of agricultural products was cultivated in periurban Hyderabad because it was profitable, not because of an ethical value of biodiversity. The fact that biodiversity is an important livelihood

strategy and of direct use for farmers implies the chance of biodiversity conservation in agricultural contexts (cf. CROMWELL et al. 2001).
Important aspects of a sustainable land use such as high species diversity, improved soils, a better microclimate and waste reduction (cf. Figure 11) can be achieved through proper management and use of agricultural biodiversity. Socioeconomic benefits such as social peace, economic power, political power, status and community empowerment have many reasons but are indirectly connected to a more sustainable land use. Empowering farmers is a viable way to strengthen on-farm conservation of agricultural biodiversity, since most farmers mentioned that diversity is of great benefit for them. Thus, sustainable livelihoods are at the same time influencing and influenced by agricultural biodiversity.

5.2 The Role of Traditional Agricultural Knowledge for Agricultural Biodiversity

This chapter addresses the question how agricultural knowledge as a contribution to agricultural biodiversity can be classified and measured and how these classifications and measures can be used in the case of Hyderabad.

"*When a knowledgeable old person dies, a whole library disappears."*
Ancient African proverb (cited in: INGLIS 1993, p. 59).

For millennia, humans have been breeding plants for food as well as for medical and other purposes. The domestication of food crops started around 10,000 years ago and has been continued with natural selection factors through exposure to different climates, pests, pathogens and weeds and selection by humans through specific traits, market needs, many other socio-economic reasons and by wide dispersal. 27,000 higher plants are currently known out of which 7,000 species with innumerable varieties are cultivated throughout the world (CIP-UPWARD 2003, p. 6).

Among these, only 15 to 20 species are today of significant economic importance (KOTHARI 1997, p. 49). Biological selection and variation make crop development comparable to natural evolution, but the difference is that it is done consciously by humans. This consciousness has been developing knowledge systems about plants, resources and technologies. Local knowledge and culture can therefore be considered as integral parts of agricultural biodiversity, because it is the human activity of agriculture which sustains or degrades biodiversity. The term *Traditional Agricultural Knowledge* (TAK) is broader than *Indigenous Agricultural Knowledge* because it is not restricted to indigenous communities from a particular geographic area but distinguishes the knowledge system from those derived from scientific and industrial communities (cf. BRUSH 2005, p. 9). Thus, the term is ambiguous:

> *"Agricultural knowledge is comprised of numerous substantive domains - soil types, pests, pathogens, environmental conditions such as rainfall and temperature patterns, and crop genotypes – as well as management domains – irrigation techniques, soil amendments, planting patterns, pest control, weed control, and, crop selection to name a few"* (ibid. p. 10).

Aspects that make agricultural knowledge "traditional" are listed below:

Traditional Agricultural Knowledge*: "Knowledge which relates to the physiochemical and biological resources available, and knowledge of the methods and technologies which are suitable for their sustainable exploitation"* (COTTON 1996, p. 160).

"Indigenous knowledge's characteristics *include (1) localness, (2), oral transmission, (3) origin in practical experience, (4) emphasis on the empirical rather than theoretical, (5) repetitiveness, (6) changeability, (7) being widely shared, (8) fragmentary distribution, (9) orientation to practical performance, and (10) holism.* ***These same characteristics apply to traditional knowledge"*** (ELLEN & HARRIS 2000, cited in BRUSH 2005, p. 9).

However, measurement of knowledge is difficult. In ethnobotanical studies, interrelations are used as indicators such as crop diversity and education of the farmer, or crop diversity correlated with the distance from a city (cf. REYES-GARCIA et al. 2008). Some authors use the participants' ability to identify certain species and report their traditional use as an indicator for TAK (cf. HAYAT et al. 2008). For this matter, BRUSH (2005, p. 11) quotes:

> *"Capturing the knowledge in a single domain by collecting its nomenclature, such as crop variety names, is relatively easy but of limited use. Linking nomenclatures of substantive domains to one another and to management domains is complicated by the inherent qualities of localness, oral transmission, and fragmented distribution. The best studies showing linkage between different domains (e.g., crop diversity and local ecological conditions) are executed in single communities or micro-regions (…). Linking multiple domains, such as crop type, soils, and plant diseases, or showing how domains are linked across regions is daunting and generally not attempted in research on traditional agricultural systems."*

For the measuring of TAK, meaningful parameters applicable to the respective region must be identified. Table 8 indicates that the "*mode of thinking*" in traditional or indigenous knowledge tends to be holistic whereas the "*western scientific*" knowledge is rather analytical which implies a reductionism since a whole system is more than the components it consist of. This is another aspect that makes measurement difficult.

Table 8: Comparison of traditional/indigenous and scientific knowledge (WOLFE et al. cited in: INGLIS 1993, p. 60)

Comparison	**Indigenous knowledge**	**Western scientific knowledge**
Relationship	Subordinate	Dominant
Dominant mode of thinking	Intuitive (holistic)	Analytical (reductionist)
Communication	Oral (storytelling, subjective experiential)	Literate/didactic (academic, objective, positivist)
Data creation	Slow/inconclusive	Fast/selective
Prediction	Short-term cycles (recognize the onset of long-term cycles)	Short-term linear (poor long-term analysis)
Explanation	Spiritual (the inexplicable)	Scientific inquiry (hypothesis, laws)
Biological classification	Ecological (inconclusive, internally differentiating)	Genetic and hierarchical (differentiating)

Traditional resource management strategies can help to maintain biodiversity and conserving soil fertility and water through practices such as biological pest control (e. g. the traditional use of *Neem* tree, *Azadirachta indica*), or the recycling and fixation of soil nutrients (cf. INGLIS 1993, p. 61). Numerous researchers agree that **farmers' agricultural knowledge is crucial in the conservation of biodiversity and that there are linkages between conserving biodiversity, food security and poverty alleviation** (e. g. ALTIERI 2002; CROMWELL et al. 2001; GRENIER 1998; GTZ 2004; INGLIS 1993; QUIROZ 1996; REYES-GARCIA et al. 2008).

In periurban Hyderabad, for this study it was attempted to gather information concerning traditional agricultural knowledge through the inquiry about crop rotation, self-production of seeds, pest management and natural fertilizers. Three categories were formed: Crop rotation, intercropping and the use of manure and/or compost was the highest category, unspecified crop rotation the second and none of these factors the third category. The participants with the broadest agricultural knowledge showed the broadest crop diversity: Those who reported a diversified crop rotation and/or intercropping as well as using manure and/or compost (23.3%, 7 respondents) had 12.4 varieties on average, those who mentioned unspecified crop rotation (43.3%, 13 respondents) had 8.3 varieties and those (33.3%, 10 respondents) who had mentioned neither crop rotation nor intercropping nor using compost and/or manure had 8.2 varieties. Positive correlations between ethnobotanical knowledge and agricultural biodiversity have been affirmed in surveys for instance in a native Amazonian society (REYES-GARCIA et al. 2008).

The existent traditional knowledge concerned soil fertility and natural pest management and could therefore contribute to save input costs for fertilizer and pesticides which would also be a step towards sustainability. The strongest positive coefficient of correlation among the tested parameters (r = 0.63) was found between *years of experience in vegetable farming* and *number of varieties* among the farming groups (cf. Chapter 4.2.3).

Maintaining the sustainable aspects of traditional land use cannot work without building farmers' associations. Since the participating vegetable producers around Hyderabad only felt loyal to their small farming group (cf. Chapters 5.1.1 and 5.1.4), community-based farmer empowerment could be a challenging issue. What else can be done to protect, preserve and promote traditional agricultural knowledge? BRUSH (2005) suggests supporting local activities since there are growing networks of indigenous knowledge resource centres (e. g. the *Andhra Pradesh Farmer Managed Groundwater System Project*, cf. Chapter 4.1.1). Yet again, it needs to be ensured that smallholder farmers are addressed. Local institutions and farmers' associations can help to raise awareness for the need of knowledge conservation and can help to improve yields and livelihoods without replacing traditional crops (BRUSH 2005, p. 33, cf. QUIROZ 1996, p. 7). A combination of traditional agricultural knowledge and modern techniques is a promising way towards sustainable agriculture.

5.3 Risks and Benefits of Wastewater Irrigation

Another selected aspect for more detailed analysis is the water quality since it turned out to be of importance for the choice of crops during the interviews. Furthermore, it is an important issue for most urban areas not only in developing countries. Good (mostly from the farmers' side) and bad attributes (mostly from scientists and officials) have been associated with the use of wastewater. The reuse of water for agriculture can certainly be regarded as a natural nutrient cycle, especially advantageous in water scarce areas. In the study by RASCHID-SALLY & JAYACODY (2008, p. 18) the use of wastewater was correlated with urban poverty and an "*almost linear relationship"* of increasing wastewater use and increasing poverty was found. This was then interpreted as the use of all available water sources especially in Asia and was also correlated with migration: Migrants formed the majority of wastewater using urban farmers in a study covering 12 cities in West Africa (ibid.), which was also found during the fieldwork for this study in periurban Hyderabad (cf. Chapter 4.2.2). Women were involved in all farming activities and in Hyderabad, they played a key role in urban farming: "*It was evident that women benefited in a myriad ways from wastewater-irrigated leafy green*

vegetable production" through employment, income from sale, diversifying the family diet and also bartering for other products in the market (BUECHLER et al. 2006, p. 254).
The associated risks have been evaluated for the case of the Musi River/Hyderabad as follows: One of the major results of the IWMI project *Ensuring Health and Food Safety from Rapidly Expanding Wastewater Irrigation in South Asia* was that the use of wastewater for irrigation poses negligible risks for producers and consumers for the investigated pathogens and heavy metals. Moreover, it was found that:

> *"Excess levels of soil-N are in large part responsible for the significantly lower rice grain yields observed in 'direct' [from the river] (…) irrigated plots as high levels of Nitrate-N are known to reduce grain yields and grain quality"* (IWMI 2008, p.30).

Instead of rice, fodder grass was cultivated for dairy farms which grew well with river water, and therefore the conclusion was drawn that "*irrigation with river water had both positive and negative effects on soil nutrient status and indicators of soil quality"* (ibid., p.30).
Another important conclusion in the publication was:

> "*Cadmium (Cd) and Lead (Pb) levels in Musi River irrigated vegetables pose negligible risk to the human food chain*" since "*contrary to general perception, total concentrations of Cd and Pb in the vegetables sampled were orders of magnitude below the Maximum Permissible Levels established by Codex Commission on Food Additives and Contaminants (CCAFC)*" (ibid., p. 36).

Another study in Bangalore indicated that lead concentrations in water hyacinth and coriander were elevated[42]. However, water hyacinth is not consumed by humans and the average intake of coriander is negligible (used as a spice). Still it remains unsure to which extent the case study of Hyderabad applies to other regions where wastewater is used.

During a small study by the author in periurban Hyderabad in 2007, it was found that less than 10% of the area was cultivated with vegetables that are usually consumed raw (only mint and coriander) which poses a low risks from pathogens. The statement by FATTAL et al. (2004, p. 4) "*a primary exposure route for the urban population in general is the consumption of raw vegetables that have been irrigated with wastewater"* seems to be of negligible importance in the case of Hyderabad. Furthermore, ENSINK et al. (2007, p. 1) found that

[42] A study by the Government Science College, Bangalore, information from an published in the "Deccan Herald", 7. 9. 2008: "These greens will sap your health".

"*unhygienic post harvest handling was the major source of produce contamination*" since the contamination with pathogens was higher in the markets than in the fields. It follows that "*interventions at the market, such as the provision of clean water to wash produce in, are better ways to protect public health and more cost effective than wastewater treatment*" (ibid; also cf. FATTAL et al. 2004).

How is it possible that the polluted irrigation water does not pose a higher risk to producers and consumers? With each irrigated field, the water filters through the ground and flows back to the river. Sedimentation in the river basin and plants like the water hyacinth (*Eichhornia crassipes*) contribute to cleaning the water. After a distance of 40 km from the city, the water looks almost clear (Figure 50).

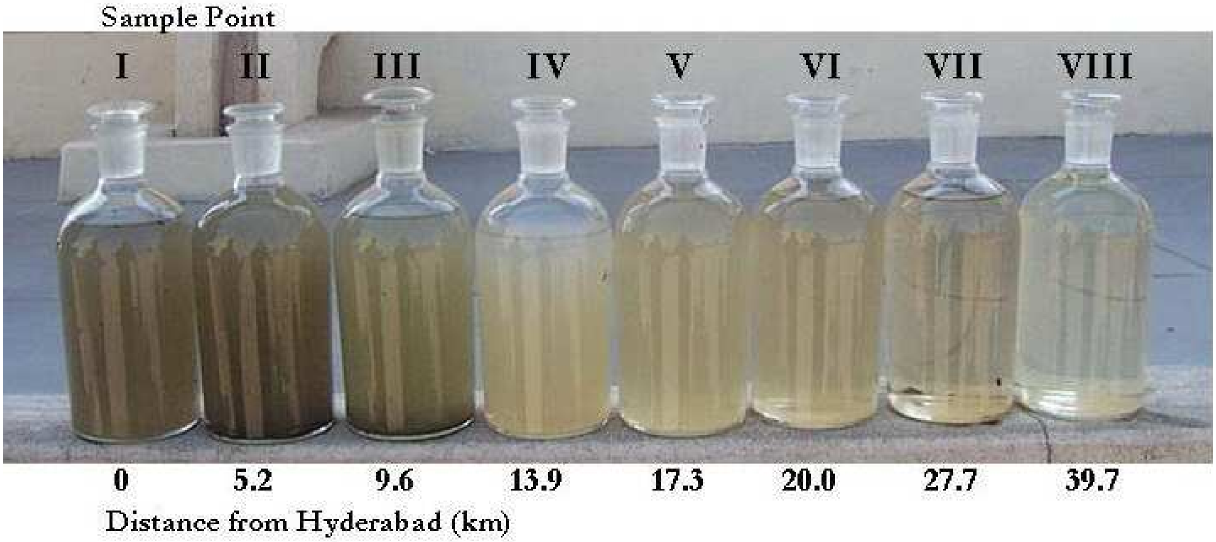

Figure 50: Water samples from different points along the Musi River. Source: ENSINK 2006, p. 47

In general, the reuse of water is more and more in the public focus. The journal *New Scientist* for instance published an article highlighting the benefits from saving fertilizer by using wastewater for irrigation in food production ("*sewage could be vital to feeding the world*"[43]). According to this article, half of the agricultural area in developing countries is irrigated with wastewater even though this is illegal in many parts of the world. The article regards it as necessary to make the practise safer and lift the bans since shortages of both water and food are imminent:

> *"Growing 1 kilocalorie of food typically requires 1 litre of water (…) with 2.5 billion extra mouths to feed by 2050, that will require at least 2000 cubic kilometres more water annually (…) that's more than twice the volume of irrigation water*

[43] Published in: New Scientist Magazine, 20 August 2008

now used worldwide. An estimated 20 per cent of the world's food is grown in urban areas. Irrigation water from sewers comes with free fertiliser in the form of the nitrates and phosphates bound up in human faeces. As the oil crisis sends fertiliser prices skyrocketing, this is a resource poor urban farmers can't afford to ignore'" (ibid.).

Coincidentally, the Indian newspaper *The Hindu* titled: "*Millions could starve as fertilizer prices soar"*[44]. Therefore the reuse of urban wastewater can be regarded a need and a reality, users must be encouraged and empowered; inherent dangers need to be minimized:

> *"A major obstacle in the process of minimising the risks lies in the non-recognition of wastewater reuse and urban agriculture as an urban livelihood strategy. Wastewater is not a priority issue for policy makers and there is no coordination among the different institutions– municipalities, water boards, departments of agriculture, and departments of land use planning, quality control agencies – that have a stake in wastewater use"* (BUECHLER et al. 2006, p. 257).

Even the small risk from pathogens can be mitigated by washing and cooking the vegetables (less than 10% of the mapped area was cultivated with vegetables consumed raw), since "even superficial washing of vegetables at home can remove an additional 99-99.9% of the viral contamination" (FATTAL et al. 2004, p. 61). As a conclusion, the assumed risks for the parameters tested along the Musi River can be regarded as negligible, whereas the benefits for livelihoods are numerous.

6 Discussion - Strengthening Resilience through Diversity?

In this chapter, the results of the case study are put into a wider context in order to find general patterns. A number of strategies supporting the livelihoods of the farmers can be extracted from the interviews, but the perspectives to support these activities need to be addressed as well. DRESCHER et al. (2006, p. 317) stated that "*Diversity of food and income resources is one of the main buffers against vulnerability of the urban poor*". But in what ways can crop diversity contribute to resilience? The *Urban Agriculture Magazine* no 22 (2009) published by the Resource Centres for Urban Agriculture and Food Security (RUAF) is titled "*The role of urban agriculture in building resilient cities*" which is supported by the findings of this study and addresses the question how urban agglomerations can profit from urban agriculture and agricultural biodiversity:

[44] The Hindu 15. 8. 2008: „Millions could starve as fertilizer prices soar"

"*Resilient cities are cities that can effectively operate and provide services under conditions of distress. Resilient cities can better absorb shocks and stresses (…) one could say that resilience is the other side of the coin of vulnerability. Rather than focusing on vulnerability, however, a focus on resilience is more positive. It means putting emphasis on what can be done by a city or a community itself, building on existing natural, social, political, human, financial, and physical capital, while at the same time strengthening its capacities."* (RUAF Homepage, 2009)

6.1 Adaptation Strategies

Several coping strategies became obvious during the study and might contribute to a certain resilience to stress factors associated with growing cities, limited resources and socioeconomic changes:

Adaptation to global change in the form of physical water scarcity as it is the case in South India (cf. AMERASINGHE 2008, slides 9 and 11: *"Physical water scarcity (water resources development approaching or exceeded sustainable limits), over 75% river flows are withdrawn for agriculture, industry and domestic use"*), can be observed in the case of migration to periurban fringes where wastewater is a reliable, uncontested water source.

The interview outcomes showed an **adaptation to several risk factors** like pests and crop diseases, yield loss e. g. through heavy rainfall, market demand and prices through crop diversity. This was possible because of the traditional use of diverse vegetables for cooking and their different properties in ecological requirements. Since monocultures are more prone to infection, diversity provides a certain resilience (ALTIERI 2002, SHIVA & PANDEY 2006).

Adaptation to the growth of the city could be observed in migration when the land was sold for construction in the research area (at least three farmers from Peerzadigudda moved to Parvatapuram during the time frame of the study since their land was sold for construction purposes). As the satellite image shows (Figure 17 a, b, c), this land is more convenient for agriculture: It cannot be used for construction as it is too close to the river. Producing perishable goods such as leafy vegetables close to the markets where they can be sold freshly is an adaptation to high transportation costs. In Hyderabad, the study showed an intense dependence on land ownership structures. To be able to pay the monthly rent, farmers felt forced to cultivate fast growing leafy vegetables. Therefore, land issues are influencing what is planted in the fields: A short-term cropping system is also an **adaptation to insecure land tenure**.

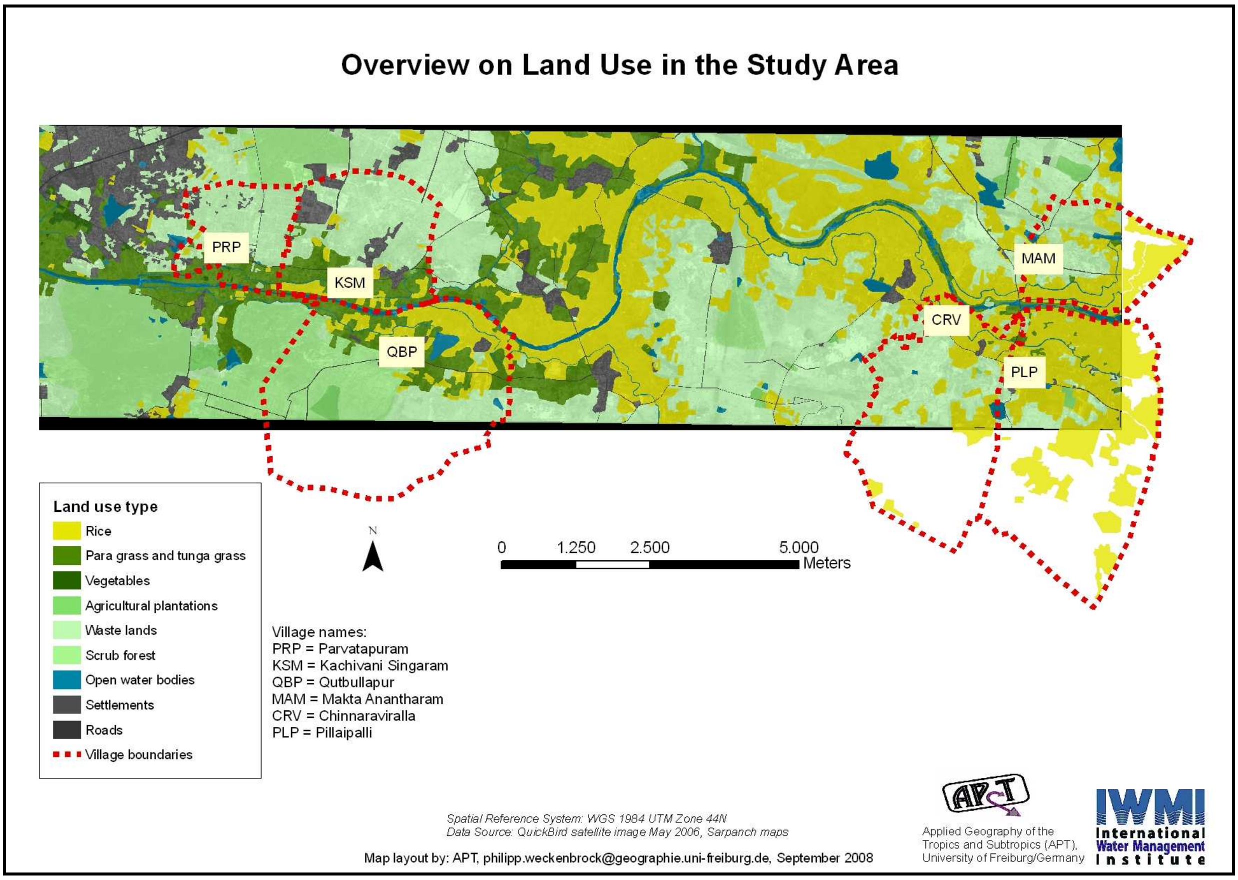

Figure 51: "In the urban fringes, rice was replaced by fodder grass" Source: IWMI 2008, p. 17

The map taken from the IWMI project (Figure 51) shows that close to the city, rice (light green) was replaced by fodder grass (dark green). This can be interpreted as an **adaptation to high pollution levels close to the city** which have negative effects on rice yield (cf. IWMI 2008, p. 16 and Chapter 5.3). The fodder grass in contrast grew well with wastewater irrigation: "*As a result of the wastewater nutrient load, no external inputs are required*" (KRISHNAGOPAL & SIMMONS 2007, p. 13).

Due to the improved water quality downstream, the water was suitable for rice cultivation from approximately 6 km distance from the city (cf. Figure 51). Another **adaptation strategy to the quality of the river water** was the cultivation of leafy vegetables instead of fruit vegetables which are able to cope with the high N-supply (cf. Chapter 5.1.3). One more **adaptation strategy to polluted water** was irrigation regulation: It was mentioned in the interviews that water was not used for irrigation on days when industrial effluents were released. These days were affirmed to be known to the farmers by experience. Strategies to clean the water where filtering through the soil and lakes where suspended solids deposit like the *Nallah Cheruvu* close to the vegetable gardens in the study site. RASCHID-SALLY & JAYACODY (2008, p. 25) list farmers' strategies from all over the world to minimize risk from wastewater use: One strategy is to store the sewage in a lake where the solids can settle out (examples from Burkina Faso, Indonesia, Nepal, Vietnam and Colombia), another possibility is to dilute the wastewater with clean water (Cambodia). Also irrigation regulation as mentioned above is reported from Burkina Faso and China. **If health risks can be managed, wastewater becomes a natural capital asset.**

6.2 The Contribution of Agricultural Biodiversity to Sustainable Livelihoods

Crop diversity is often reduced to an exclusively natural asset but it should be seen as a dynamic system with social, economic, environmental and biological components which are not only part of the natural capital, but also of the human, social and financial capital (cf. CROMWELL et al. 2001, p. 100). The Convention on Biological Diversity promotes in–situ conservation on farms in order to sustain genetic diversity as well as the whole ecosystem.

In the context of this study with polluted water and soils, dependence on high external inputs and pesticides, the question might arise whether topics of biodiversity and sustainable land use are relevant. There are good reasons to answer this question positively: Biodiversity exists even under the difficult frame conditions described above and contributes to the livelihoods of the periurban farmers as this study indicates. Regardless of the frame conditions, existing genetic diversity must be explored and sustained as many authors emphasise (BIROL et al. 2007; CIP-UPWARD 2003; ESQUINEZ-ALCAZAR 2005; SHIVA 2000; SMIT 2000; THRUPP 2003). The importance of biodiversity is further reflected in a growing global discourse (CBD; MDG no 7; cf. Chapter 2.4).

Direct uses of agricultural biodiversity are a **dietary diversity** (providing minerals, vitamins and proteins) through self-consumption of the cultivated vegetables and thus a contribution against malnourishment, and productivity in **financial assets** through their sale and bartering.

Indirect uses are **adaptation** to high input prices (seeds, fertilizer, pesticides…), to water scarcity through the use of a reliable wastewater source, the **reduction of risk** through cultivation of plants with different agro-ecological requirements; losses due to the failure of one particular crop can possibly be compensated with the yield of the others. However, there are certain factors that can render farmers' livelihoods insecure in terms of ecological, social or economic aspects. Insecurity emerges for instance directly through the potential health risks from industrial wastewaters, indirectly through soaring fertilizer prices and insecure land tenure.

CROMWELL et al. (2001, pp. 96-97) state an ***insurance value*** in crop diversity against future adverse conditions, an ***exploration value*** for yet unknown resources and, furthermore, an ***existence value*** in an ethical sense. Usually smallholder farmers have been weaker in profiting from diversity than stakeholders controlling access through intellectual property rights and need therefore to be empowered. An *"increasing voice of farmers' and civil society organisations*" has been remarked (ibid., p. 97).

Also in periurban Hyderabad, agriculture contributed to livelihoods and food security of the persons interviewed for this study and should therefore be encouraged. Farmers were aware of these benefits as the interviews showed. Most indicative were the answers given to the question "*Why do you have such a broad diversity of vegetables"*? The answers were e. g. "*To be able to react to fluctuating market prices*", "*to be resilient against pests, against the loss of yield in one vegetable*" or "*To be less vulnerable against increasing seed prices for one vegetable*" and "*to consume some of it myself, to be able to take whatever I need*".
CROMWELL et al. (2001, p. 93) see the benefits from agricultural biodiversity in providing food, medicine and construction material, also in industrial farming systems. Conservation and evolution of crops is a long-term aspect in this context. A short-term outcome is the standard of living (food security, wellbeing, income and resilience) and a long-term outcome, the balance and sustainability of livelihood strategies and resource use.
UPA is believed to be characterized by high biodiversity and to be more sustainable than conventional rural agriculture. A study in Washington, USA showed that with emerging UPA, the number of available tomato varieties in the markets rose from eight to 74 (SMIT 2000). It was concluded that ***"urban agriculture is an effective tool to slow down the loss of biodiversity*"** (ibid., p. 12).

6.3 Constraints and Perspectives for Urban and Periurban Agriculture

Urban and periurban agriculture is a way to meet challenges such as rising food prices and reduces the dependence on external resources. Around 200 million persons worldwide are involved in UPA and provide 15 to 20% of the world's food (ARMAR-KLEMESU 2000, cited in: FAO 2007b), often due to reasons like unreliable access to food supplies (lack of availability and/or purchasing power) and the lack of employment opportunities. Therefore, UPA has been titled as "*a response to crises*" and was regarded as a "*crisis induced strategy*", (DRESCHER et al. 2000; SMIT 2000), but also in a positive way of becoming less vulnerable. KRISHNAGOPAL & SIMMONS (2007) list some benefits from UPA such as the provision of livelihoods and the addressing of food and nutritional security. The re-use of organic waste and wastewater (cf. YASMEEN 2001, PATEL 2003) is a possibility to recycle nutrients in times of a global fertilizer crisis. Economic development on the micro level could be beneficial especially for women. Transport costs are saved due to proximity to markets. Green zones within the city can directly contribute to improve the microclimate and well-being of city dwellers (YASMEEN 2001, p. 27). The journal *New Scientist* titled in 2007 "*Green roofs could* *cool warming cities*"[45]. In the article it is stated that leafy walls and roofs can lower air temperatures significantly and help to save the energy required for air conditioners. Rooftop gardens have been successfully implemented for instance in Senegal by women's groups (SAYDEE & UYEREH 2003). YASMEEN (2001, p. 28) stated "*there is a clear link between UPA and the nexus between human and environmental health*".

Figure 52: Urban agriculture can help to build resilient cities. Source: Resource Centres for Urban Agriculture and Food Security (RUAF)

Figure 53: Cultivation of vegetables in plastic bags. Source: Cityfarmer Homepage

However, there are also inhibiting structures that apply also to the case of Hyderabad: In general, there is a lack of awareness among policy makers and the public so that the potential benefits of UPA are neither recognised nor supported (cf. KRISHNAGOPAL & SIMMONS 2007, p. 27). Moreover, UPA is rarely organised in farmers' associations. Since institutions do not focus on UPA, knowledge transfer and training materials e. g. for sustainable land use and integrated pest management are missing (ibid.; also cf. IWMI/RUAF 2007*)*. Agricultural activities are inhibited by escalating land prices and the lack of available land. Pollution through industrial effluents and the use of highly toxic pesticides could affect the farmers' health, community and environmental health In Hyderabad, 1,600 acres of agricultural land could be lost to the *"Musi Beautification Programme"* which aims to cover and channel the river to create parks (ibid., p. 31). In spite of urban farmers who achieved a delay through protest, city authorities plan to implement the programme[46]. Thousands of

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[45] New Scientist, October 6th, 2007: "'Green Roofs' could cool warming cities".

[46] The Hindu, September 8th 2008: "Musi Beautification: GHMC Chief for Speedy Work"

persons depend on this land for their livelihoods often without viable alternatives. Further constraints are degraded soils, absent insurance against hazards and the lack of seasonal labourers to support the farmers (IWMI/RUAF 2007, p. 21). This point was also confirmed by 3 participants (all of them landowners) during the interviews for this case study.

There is a clear need for **farmers' associations** and **the integration of UPA in urban planning** (title of the *Urban Agriculture Magazine* no 4 by the RUAF Foundation in 2001). A good example is Dar Es Salaam, where UPA has been integrated in urban planning through a bottom-up approach (KITILLA & MLAMBO 2001). There is also a need for **agricultural extension services** targeting smallholders like FAO field schools that educated more than one million farmers so far in integrated pest management (CROMWELL et al. 2001, p. 107).
Another possibility of **education and awareness rising** are school gardens[47]. The advantage is that children who are particularly prone to malnutrition in India can directly benefit from self-grown fruit and vegetables. This could contribute to the *Millennium Development Goals* 1 and 2 *("end poverty and hunger, universal education")*. Certain *Regional Resource Centres* provide **information services, training** and **policy advice,** but also **monitoring** and **capacity building** are focused by farmers' associations. However, they are mostly from rural Andhra Pradesh (KRISHNAGOPAL & SIMMONS 2007, pp. 15-18).
Eventually, probably the most important issue for UPA in order to become a viable and sustainable option for city dwellers is capacity building. Policy makers as well as key enablers such as NGOs and development organisations need to be united. There is the example of the ***Rythu bazaars***[48] in Hyderabad, where farmers can sell their products directly without a middleman. Six such markets have been established by the government in the city, since farmers and customers felt exploited by intermediaries. In the *Rythu bazaars*, prices are low and the vegetables are fresh. Women, who are not involved in wholesale purchase activities, can also retail non agricultural products in *Rythu bazaars.* As the infrastructure between the *Rythu bazaars* and the periurban and rural areas around Hyderabad are still weak, many farmers still sell their products to middlemen (cf. KRISHNAGOPAL & SIMMONS 2007, pp. 14 and 17). Also in this study, less than 10% of the interviewed farmers reported to sell their vegetables themselves. The lack of time was mentioned as the main reason for this fact.

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[47] The RUAF-CFF programme *("Towards a food and nutritionally secure future: Establishment of kitchen gardens and school garden 'bright spots' in Serilingampally*") is to establish productive kitchen gardens for households and school gardens for in Hyderabad.

[48]The Hindu, January 8th, 2004: "Door-delivery of vegetables from rythu-bazaar"

Concerning the perspectives of UPA, the following considerations are discussed by different stakeholders and are applicable for the city of Hyderabad:

Input costs in UPA could be saved by own seed production, avoiding chemical fertilizers and pesticides through composting, applying manure from cattle and green manure such as sunnhemp or different legumes. An ideal example in the case study was the (groundwater-irrigated) garden of the key-informant during the interviews, but strongly knowledge-dependent.

Composting has been discussed as a viable option to meet rising fertilizer prices and to close nutrient cycles:

> *"If city waste would instead be composted before applying it to the soil, cities would be cleaned up and the fields around cities would be spared the declining levels of fertility induced by today's accumulating plastic-film waste, while health and hygiene in periurban areas would visibly improve"* (PATEL 2003, p. 37).

The city of Bangalore could serve as an example, where civil society organisations produce and distribute considerable amounts of compost (YASMEEN 2001, p. 8). A project to avoid the ever increasing amount of wastewater is a toilet without water (*ECOSAN*), where the urine and faeces can be directly used as a natural fertilizer[49].

For the case of Hyderabad, the potential of **rainwater harvesting** is currently discussed which was the traditional system of storing water in great lakes. During the monsoon, rainwater could be harvested for instance from rooftops. Storage facilities could consist of tanks that are often already existent near the houses (cf. AMERASINGHE et al. 2008; VAN ROOIJEN et al. 2005).

Seed production could be enhanced by farmers' education. In periurban Hyderabad, seeds can be produced by growing singular pants between the fields as observed in some gardens during the interviews. The World Vegetable Centre (AVRDC 2005) published a manual with instructions for seed production for the most important vegetable varieties, but also for amaranth and malabar spinach. Since the majority of the interviewees could neither read nor write knowledge transfer should be implemented through farmer field schools or through pictorial fact sheets so that the information reaches the target group. The aforementioned RUAF-CFF project tries to promote seed production for kitchen gardens in Hyderabad[50].

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[49] Ecological Sanitation is a method to recycle human excreta without water. It helps to mitigate risks from pathogens and contributes to food security through providing natural fertilizer since very human being produces the amount of nutrients that are necessary to produce the food for one person (BUECHLER et al. 2006, p. 253). More information: http://www.thewaterpage.com/ecosan_main.htm

[50] For more information see RUAF homepage (http://www.ruaf.org/node/448), or IDRC (www.idrc.ca)

Organic farming is increasingly regarded as a viable option especially for smallholders to use their land sustainably and to increase their productivity (cf. SHIVA & PANDEY 2006). A study by UNEP-UNCTAD (2008, foreword), which was also based on the SLA, found that "*organic agriculture can be more conducive to food security in Africa than most conventional production systems, and that it is more likely to be sustainable in the long term*". All case studies in Africa focusing on organic food production have shown increases in productivity (ibid., p. 51) and it follows that:

> *"Organic and near-organic agricultural methods and technologies are ideally suited for many poor, marginalized smallholder farmers in Africa, as they require minimal or no external inputs, use locally and naturally available materials to produce high-quality products, and encourage a whole systemic approach to farming that is more diverse and resistant to stress"* (ibid.).

The findings by UNEP-UNCTAD (2008, p. 9) are "*backed up by studies from Asia and Latin America that concluded that organic farming can reduce poverty in an environmentally friendly way.*" Since organic farming can enhance agricultural biodiversity[51] as well as sustainable livelihoods (UNEP-UNCTAD 2008), it should be promoted and combined with traditional agricultural knowledge which is often well adapted to the specific habitat conditions. Such a strategy is the bottom-up approached *Natural Resources Management* (NRM) which focuses on resource-poor farmers and combines traditional agricultural knowledge with aspects of organic agriculture (ALTIERI 2002). The FAO (2007a, p. 43) sees opportunities for UPA from the growing demand for organic foods and recommends supporting information, research, trainings and assistance for safe and sustainable UPA. As supporting organisations and programmes are named: IDRC, FAO, RUAF, Urban Harvest, IWMI and UN-HABITAT (ibid., p. 71).

In India in general, there is a lot of interest in alternative agriculture and its link with integrated resource management and social sustainability (YASMEEN 2001, p. 14*).* According to YASMEEN (2001, p. 26), of particular importance for further research is the role of women in the Indian food system. Also the non-market uses of crop diversity such as ecosystem functions need to be supported through awareness-raising. There are numerous organizations dealing with urban agriculture in India who need to be connected and empowered. The first entry point to enhance UPA is therefore to strengthen activities and associations that already exist rather than starting new activities (CROMWELL et al. 2001, p. 98; YASMEEN 2001, p. 25).

[51] For instance research results by the FiBL (Research Institute of Organic Agriculture), Switzerland point to this matter: (www.fibl.org)

6.4 Reflection of the Conceptual Framework and the Fieldwork Methods used

To link ecological and socioeconomic approaches was one of the most important strategies of the study design. This is crucial to approach factors that play a role for decision making in the use of natural resources:

> *"When it comes to methods for studying traditional ecological knowledge, I have learned far more from social scientists than from biologists. But neither natural scientists nor social scientists can do the job well without the expertise of the other"* (JOHANNES cited in INGLIS 1993 p. 43).

One obvious problem was the extractive character of the fieldwork: Although discussions with farmers were very rewarding and informative for the study, they were not really participative as the study design was developed by the author with advice of the supervisors. Exceptions were the rankings where the participants had to find examples and reflect their own decision making. To return some of the gathered knowledge in order to empower farmers would be possible through a broader project where local stakeholders could participate in implementation of well considered action like farmer field schools. CHAMBERS (1992, p. 14) suggests participative rural appraisal techniques (of course transferable to urban environments) which are supposed to be less extractive than mere questionnaires. The guiding topic of this approach is "*seeking diversity rather than averages*". Working with participatory approaches makes it more likely that the target group will reflect the new information and discuss the findings. Participatory implementation of recommendations is therefore more likely to be successful (ibid., p. 21).

It is also important to mention that statistical analysis in social science is limited; it does not provide absolutely valid knowledge, results remain always preliminary (cf. ATTESLANDER 2008, p. 231). This applies for biodiversity calculations as well; one could argue that the distinction of named varieties as mentioned by the informants gives little information about genetic diversity. For instance, *Amaranthus tricolor* red and green variety were named as two different vegetables although they belong to the same species and therefore genetically not much distant from each other (cf. SMALE 2007, p. 8).

The preconception that a foreign researcher is likely to have, that farmers who use wastewater for irrigation are in a desperate situation is not adequate. Most of the interviewees in this study were proud of their work and expressed contentment: "*I like the work here. Growing vegetables is a good job*". As another example, a women of around 50 years stated "*Without trouble, what would be the game?"*

As CROMWELL et al. (2001, p. 101) state, an integrated approach is imperative to better understand the contribution of agricultural biodiversity to livelihoods "*because of the significant spillover effects and feedback loops that operate"*. The sustainable livelihoods approach provides an adequate basis to analyse somebody's living circumstances, to give an impression about vulnerability and adaptation strategies. If the SLA is regarded as a flexible basis one can alter it according to the research questions, taking into account culture, gender or, in this case, agricultural biodiversity. It is very flexible and puts the focus on certain indicators that can help in understanding structures and behaviour. In this case study, the sustainable livelihoods framework helped to approach some aspects of the livelihood context of farmers depending on various factors such as wastewater (cf. BUECHLER 2004, p. 29). However, it is difficult to capture irrational decisions and behaviour with the SLA, since humans do not always act like a *homo economicus* and analysis of decision making according to the assets may give an incomplete overview. Emotional inner realities as well as personalities play an important role. Therefore, BAUMGARTNER & HÖGGER (2004) developed a framework with both inner and outer realities (Figure 54). For further research with a stronger focus on individuals, this tool could be helpful for better understanding human behaviour.

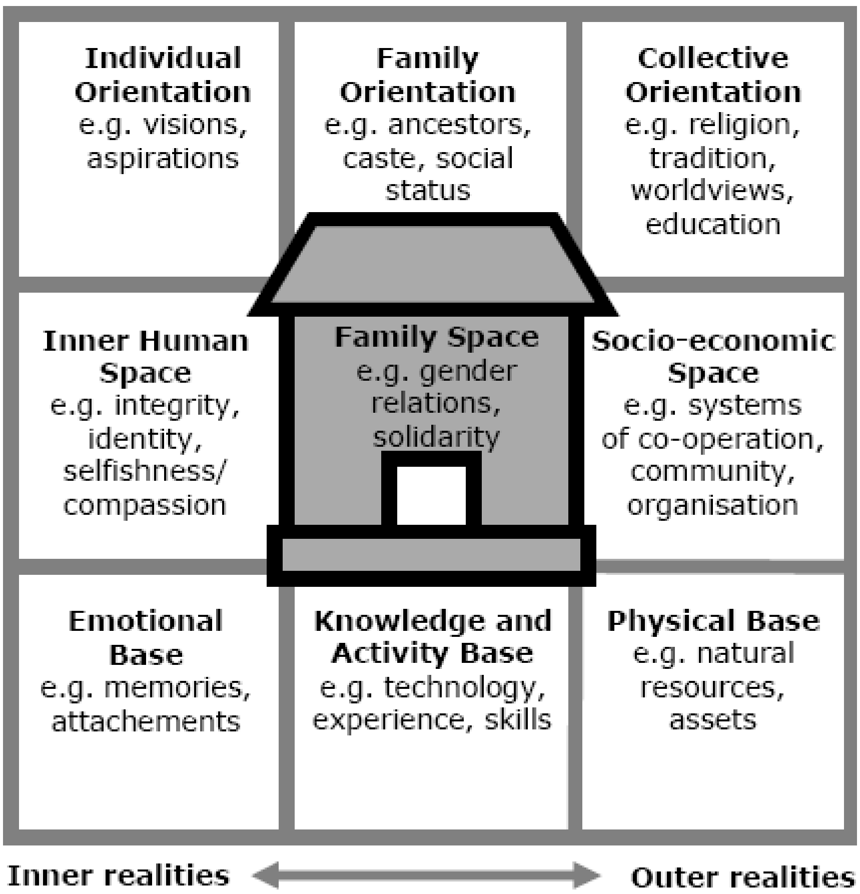

Figure 54: The *Rural Systems Livelihoods Mandala* as a heuristic tool for approaching livelihood. Source: BAUMGARTNER & HÖGGER 2004

7 Conclusion and Perspectives

In Hyderabad, the expanding IT sector accelerates rapid urbanisation as well as migration of farmers from traditionally rainfed agricultural systems in rural Andhra Pradesh in search of work. Due to the population rise, land prices have been increasing steadily, putting UPA under pressure since less and less land suitable for agriculture is available. At the same time, demand for food is growing and the production of perishable goods close to the city provides food and incomes (cf. KRISHNAGOPAL & SIMMONS 2007, p. 9).

The results of this case study suggest that agricultural biodiversity can contribute to sustainable livelihoods and generate a certain resilience to economic and ecological stress factors.

Against the background of the findings of the IWMI project evaluating risks and benefits from wastewater irrigation, vegetables continue to be the major risk factor for producers and consumers. However, the evaluated health risks were classified as negligible for the parameters tested (IWMI 2008, pp. 48-51). Farmers' livelihood and adaptation strategies found in this case study were the use of wastewater for irrigation in an area where water is scarce and the diversification of crops and the cropping system to reduce risks. Most farming groups had a very short cropping cycle and were in an insecure situation concerning land tenure. They were exposed to pesticides, to industrial effluents and dependent on seed and fertilizer prices. Agricultural biodiversity was strongly regarded as something positive mostly for economic reasons, but also because it was seen to provide resilience against ecological factors. It therefore needs to be maintained, safeguarded and promoted through empowerment of the farmers. Nevertheless, the assumed risks and stress factors should be mitigated through farmer education and awareness raising among policy makers concerning the handling of pesticides, organic alternatives and soil fertility tending. Against the background of this study, wastewater can be regarded as natural capital in the sustainable livelihoods context (cf. BUECHLER 2004, p. 27).

The information gathered in the interviews suggests that agricultural biodiversity is more than a short-term adaptation strategy. It is an important part of the set of livelihood strategies and can help to mitigate vulnerability. Perspectives to encourage a sustainable development and use of natural resources at the **micro level** are the implementation of the use of compost and manure as non-mineral fertilizers, "home" production of vegetable seeds, rainwater harvesting and to enhance organic agriculture for smallholder farmers in order to render their production systems less input intensive. As this study indicates, it may not be necessary that each of them participates in farmer field schools since knowledge is distributed among the farmers (cf. Chapter 5.1.3). Furthermore, farmers can empower themselves by forming interest groups. On the **meso level**, it should be assured that industrial effluent is separated from domestic effluent which can be profitable for farming. This requires technical solutions, law implementations and evaluation of the factories releasing effluents into the water bodies. Water sources must be appropriate for regional conditions with a reliable distribution system. On the **macro level**, nutrient cycles and water catchments must be examined as well as the political environments and policymakers' attitude towards UPA, which needs to be integrated into urban planning.

The aforementioned *Crop Diversity Trust*, which has the aim to conserve all existing agricultural varieties[52] suggests a number of ways to conserve agricultural biodiversity, in-situ as well as ex-situ, saying that "*farmers and rural communities can be encouraged and supported to conserve their traditional varieties by continuing to grow them on their farms"* (Homepage Crop Diversity Trust). An international mandate to maintain and promote agricultural biodiversity is provided by the Convention on Biological Diversity and the institutions in charge of implementing the decisions made at the Conferences of the Parties (COP).

From this study it follows that vegetable farmers along the Musi River benefited in many ways from agricultural biodiversity, not only in terms of food and income, but also with regard to socioeconomic aspects. This was true for groundwater and for wastewater users likewise. Biodiversity was not significantly lowered by wastewater irrigation, but numerous factors besides water quality influenced the crop choice, from economic, ecological and social contexts. Therefore, addressing biodiversity in agricultural systems clearly requires a holistic approach such as the *Sustainable Livelihoods Approach* covering natural resources as well as socioeconomic aspects. It is important not to base approaches on particular plants or yield but on whole production systems enabling producers to become more resilient through diversity and promoting the numerous benefits of a high agricultural diversity and less reliance on external inputs. Maintaining and enhancing a broad agricultural biodiversity may be labour and knowledge intensive but is more sustainable for nature and humans than intensified, high-input monocultures.

[52] The *Crop Diversity Trust* is currently constructing an "Arctic Seed Vault" in Spitzbergen, Norway, for the conservation of all existing agricultural plants implemented in 2006. More information at: http://www.croptrust.org/main/arctic.php?itemid=211.

References

ADJAYE-GBEWONYO, K. (2008): Farmers' Perceptions of Benefits and Risks from Wastewater Irrigation in Accra, Ghana. In: Urban Agriculture Magazine no. 20, RUAF Foundation, pp. 27-28.

ALTIERI, M. (2002): Agroecology: The science of natural resource management for poor farmers in marginal environments. In: Agriculture, Ecosystems and Environment, 1971 (2002,) pp. 1–24. Available at: http://www.agroeco.org/doc/NRMfinal.pdf.

ALTIERI, M. & ROSSET, P. (1999): Ten reasons why biotechnology will not ensure food security, protect the environment and reduce poverty in the developing world. AgBioForum, 2(3&4), pp. 155-162. Available at: http://www.agbioforum.org.

ALTIERI, M., ROSSET, P. & THRUPP, L. (1998): The Potential of Agroecology to Combat Hunger in the Developing World. Paper provided by International Food Policy Research Institute (IFPRI) in its series 2020 vision briefs with number 55.

AMERASINGHE, P. (2008): Water for a secure world. IWMI's Strategic plan (2009–2013). Edited by: International Water Management Institute (IWMI), South Asia Regional Office, Patancheru.

AMERASINGHE, P., DEVENISH, C. & SULEMAN, K. (2008): Rainwater Harvesting Potential for Urban Agriculture in Hyderabad. In: Urban Agriculture Magazine no. 20, RUAF Foundation, pp. 34-36.

APFMAGS (2006): Nourishing Traditions - Local Greens. Andhra Pradesh Farmer Managed Groundwater Systems Project, Hyderabad.

ATTESLANDER, P. (2008): Methoden der empirischen Sozialforschung. 12., durchges. Aufl., Schmidt (ESV basics), Berlin.

AVRDC (2003): Suggested Cultural Practices for Indigenous Vegetables. Chang, M & Palada, L. AVRDC International Cooperator's Guide. Available at: http://www.avrdc.org/LC/indigenous/

AVRDC (2005): Saving your own Vegetable Seeds. Available at: http://www.avrdc.org/pdf/PROD6-saving_your_own_vegetable_seeds.pdf

AYERS, R. & WESTSCOT, D. (1985): Water quality for agriculture. Food and Agriculture Organization (FAO irrigation and drainage paper, 29, Rev. 1), Rome.

BAHRENBERG, G. & GIESE, E. (1975): Statistische Methoden und ihre Anwendung in der Geographie. B. G. Teubner (Studienbücher der Geographie), Stuttgart.

BAMJI, M. (2005): Impact of Green Revolution on Food Security. National Institute of Nutrition, Hyderabad. Available at: http://nutritionfoundationofindia.res.in/archives.asp?archiveid=211&back=bydate.asp

BAUMGARTNER, R & HÖGGER, R. (2004): In search of sustainable livelihood systems – Managing resources and change. Sage Publications, New Delhi.

BIROL, E., KONTOLEON, A. & SMALE, M. (2007): Farmer Demand for Agricultural Biodiversity in Hungary's Transition Economy: A Choice Experiment Approach. In: Smale, M. (ed.): Valuing Crop Biodiversity. On-farm genetic resources and economic change. CABI Publications, Wallingford, UK, pp. 32-44.

BOZZINI, A. (2004): Vegetable Research and Poverty Alleviation. In: Nath, P., Gaddagimath, P. &. Dutta, O. (2004): Food Security and Vegetables - A Global Perspective. Dr. Prem Nath Agricultural Science Foundation, Bangalore, India, pp. 101-111.

BRUSH, S. (2005): Farmers' Rights and Protection of Traditional Agricultural Knowledge. In:

CAPRi Working Paper, vol. 36, pp. 1–47.

BUECHLER, S. (2004): A Sustainable Livelihoods Approach for Action Research on Wastewater Use in Agriculture. In: Scott et al. (2004): Wastewater Use in Irrigated Agriculture - Confronting the Livelihood and Environmental Realities. Cabi International in association with IDRC and IWMI, Ottawa, Colombo, pp. 25-40.

BUECHLER, S. &. DEVI, G. (2002): Livelihoods and Wastewater irrigated Agriculture - Musi River in Hyderabad City, Andhra Pradesh, India. In: Urban Agriculture Magazine no. 8, RUAF Foundation, pp.14–17.

BUECHLER, S., DEVI, G. & DEVI, R. (Directors, 2003): Making a Living along the Musi River near Hyderabad, India. Documentary video co-produced by the International Water Management Institute (IWMI), Department of International Development (DFID), UK and the Resource Center on Urban Agriculture and Food security (RUAF)-ETC-Netherlands Foundation, The Netherlands.

BUECHLER, S., DEVI, G. & KERAITA, B. (2006): Wastewater Use for Urban and Peri-Urban Agriculture. In: Van Veenhuizen, R. (ed.): Cities farming for the future. Urban Agriculture for Green and Productive Cities. RUAF Foundation: International Institute of Rural Reconstruction; International Development Research Centre, pp. 244-260, Silang, Ottawa.

CHAMBERS, R. (1992): Rural Appraisal: Rapid, Relaxed and Participatory. IDS Discussion Paper 311, Institute of Development Studies, University of Sussex, Brighton.

CHAMBERS, R. & CONWAY, G. (1992): Sustainable rural livelihoods. Practical concepts for the 21st century. Institute of Development Studies (Discussion paper / Institute of Development Studies, 296), Brighton.

CIP-UPWARD (2003): Conservation and Sustainable Use of Agricultural Biodiversity: A Sourcebook. International Potato Center –User's Perspectives with Agricultural Research and Development, Los Banos, Philippines, 3 Volumes.

CLEMETT, A. &. ENSINK, J. (ed., 2006): Farmer driven wastewater treatment: A case study from Faisalabad, Pakistan. Available at: http://wedc.lboro.ac.uk/conferences/pdfs/32/Clemett.pdf.

COTTON, C. (1996): Ethnobotany. Principles and Applications: John Wiley & Sons, Chichester.

CROMWELL, E., COOPER, D & MULVANY, D. (2001): Agriculture, Biodiversity and Livelihoods: Issues and Entry Points for Development Agencies. In: Koziell, I. & Saunders, J.: Living Off Biodiversity: exploring livelihoods and biodiversity issues in natural resources management, pp. 75-112.

DANSO, G. & MOUSTIER, P. (2006): Local Economic Development and Marketing of Urban Produced Food. In: Van Veenhuizen, R. (ed.): Cities farming for the future. Urban agriculture for green and productive cities. Silang Philippines, Ottawa: RUAF Foundation: International Institute of Rural Reconstruction; International Development Research Centre. pp. 147-195.

DFID (2001): Sustainable Livelihoods Guidance Sheets. Department for International Development, London.

DFID (2002): Better livelihoods for poor people: The role of Land Policy. Department for International Development - Consultation Document. London.

DRESCHER, A. W. (1998): Hausgärten in afrikanischen Räumen. Bewirtschaftung nachhaltiger Produktionssysteme und Strategien der Ernährungssicherung in Zambia und Zimbabwe. Centaurus-Verl.-Ges. Sozioökonomische Prozesse in Asien und Afrika, Bd. 4, Pfaffenweiler.

DRESCHER, A. W. & BOS, F. (1994): Report on the Zambian Homegarden Project and the Rural Household Food Security Survey. Publication of the FAO Project FAHNIS "Food, Health and Nutrition Information System", Lusaka, Zambia.

DRESCHER, A. W., JACOBI, P. & AMEND, J. (2000): Urban Agriculture, a response to criris? In: Urban Agriculture Magazine no. 1, RUAF Foundation, Maiden Issue, pp. 6-8.

DRESCHER, A. W., HOLMER, R. &. IAQUINTA, D. (2006): Urban Homegardens and Allotment Gardens for Sustainable Livelihoods: Management Strategies and Institutional Environments. In: Kumar, B. & Nair, P. (ed.): Tropical Homegardens. A Time-Tested Example of Sustainable Agroforestry, pp. 317-338.

ENSINK, J., MAHMOOD, T. & DALSGAARD, A. (2007): Wastewater irrigated vegetables: market handling versus irrigation water quality. Tropical Medicine and International Health, volume 12 suppl. 2 pp 1–6 december 2007

ENSINK, J. (2006): Wastewater Quality and the Risk of Hookworm Infections in Pakistani and Indian Sewage Farmers. London School of Hygiene and Tropical Medicine.

ESQUINEZ-ALCAZAR (2005): Protecting Crop Genetic Diversity for Food Security: Polotical, Ethnical and Technical Challenges. In: Nature Vol. 6, pp. 946-953.

FATTAL, B., LAMPERT, Y. & SHUVAL, H. (2004): A Fresh Look at Microbial Guidelines for wastewater Irrigation in Agriculture: A Risk-assessment and Cost-effectiveness Approach. In: Scott et al. (2004): Wastewater Use in Irrigated Agriculture - Confronting the Livelihood and Environmental Realities. Cabi International in association with IDRC and IWMI, Ottawa, Colombo, pp. 41-58.

FAO (2005): A System of Integrated Agricultural Censuses and Surveys. World Programme for the Census of Agriculture 2010. Rome.

FAO (2006): The State of Food Insecurity in the World 2006. Eradicating world hunger - taking stock 10 years after the World Food Summit. Rome.

FAO (2007a): SARD and Agricultural Biodiversity. (Sustainable Agriculture and Rural Development (SARD), Policy Brief 16. Rome. Available at the Organic Agriculture Centres Alliance (ORCA), www.fao.org.

FAO (2007b): Profitability and Sustainability of Urban and Peri-urban Agriculture. Agricultural Mangement, Marketing and Finance Occasional Paper, no. 19, Rome.

FAO (2008a): Soaring Food Prices: Facts, Perspectives, Impacts and Actions required. High Level Conference on World Food Security: Challenges of Climate Change and Bioenergy. Rome.

FAO (2008b): Current World Fertilizer Trends and Outlook to 2011/12. Rome.

FAO/WHO Expert Consultation (ed., 2003): Diet, nutrition and the Prevention of Chronic Diseases. In: WHO Technical Report Series, 916. Geneva.

FRESCO, L. & BAUDOIN, W. (2004): Food and Nutrition Security Towards Human Security. In: Nath, P., Gaddagimath, P. &. Dutta, O. (2004): Food Security and Vegetables - A Global Perspective. Dr. Prem Nath Agricultural Science Foundation, Bangalore, India, pp. 7-42.

GIBBON, D. &. PAIN, A. (1985): Crops of the Drier Regions of the Tropics. Longman Scientific & Technical, Essex.

GRAGNOLATI, M., SHEKAR, M., DAS GUPTA, M., BREDENKAMP, C. & LEE, Y. (2005): India's Undernourished Children: A Call for Reform and Action. Worldbank HNP Discussion Paper, Washington, DC.

GRENIER, L. (1998): Working with Indigenous Knowledge - A Guide for Researchers. IDRC (International Development Research Centre), Ottawa.

GTZ (2004): When Nature and Culture Meet: People, Food and Biodiversity. In: Themenblätter People, Food and Agrobiodiversity. Eschborn.

GTZ (2007): Agrobiodiversität – Eine Möglichkeit zur Minderung von AIDS-Folgen. In: Themenblätter People, Food and Agrobiodiversity. Eschborn.

HAYAT, M., KHAN, M., SHAHEEN, N., YASMEEN, G. & AKHTER, S. (2008): Ethnotaxonomical approach in the identification of useful medicinal flora in Pakistan. Ethnobotany Research & Applications, Vol 6, available at: www.ethnobotanyjournal.org/vol6/i1547-3465-06-035.pdf.

HILL, M. (1973): Diversity and Evenness: A Unifying Notation and Its Consequences. Ecology, Vol. 54, No. 2, published by: Ecological Society of America, pp. 427-432. Available at: http://www.jstor.org/stable/1934352.

IAQUINTA, D. &. DRESCHER, A. W. (2000): Defining Periurban: Towards guidelines for understanding rural-urban linkages and their connections to institutional contexts. Land Reform 2000/2, FAO, Rome, pp. 8-27.

IDRC (2005): Urban Poverty and Environment. Prospectus 2005-2010. International Development Research Centre Program and Partnership Branch, Ottawa.

INGLIS, J. (1993): Traditional Ecological Knowledge Concepts and Cases: International Development Research Centre, Ottawa.

IWMI (2008): An Atlas of Water Quality, Health and Agronomic Risks and Benefits Associated with "Wastewater" Irrigated Agriculture. A Study from the Banks of the Musi River, India. Contributions by: P. Weckenbrock, R. Simmons, R. Acharya, A. Drescher & P. Amerasinghe. International Water Management Institute, South Asia Regional Office, Patancheru.

IWMI/RUAF (2007): Potential for Urban and Periurban Agriculture in Serilingampally Circle, Hyderabad. Creating a food and nutritionally secure future. A concept document presented to a multi-stakeholder forum. IWMI South Asia Regional Office, Patancheru.

JOHNSON, A. (2008): Geogenic Contaminants. EAWAG News 65e, Dübendorf. Available at: http://www.eawag.ch/services/publikationen/eanews/news_65/en65e_johnson.pdf

KASPERSMA, J. (2002): Agricultural Use of Untreated Urban Wastewater in Low Income Countries. In: Urban Agriculture Magazine no 8, RUAF Foundation, pp. 5-6.

KENNEDY, E. & BOUIS, H. (1993): Linkages between Agriculture and Nutrition: Implications for Policy and Research. International Food Policy Research Institute (IFPRI), Washington.

KITILLA, M. & MLAMBO, A. (2001): Integration of UPA in Urban Planning. In: Urban Agriculture Magazine no. 4, RUAF Foundation, pp. 22-24.

KOTHARI, A. (1997): Understanding Biodiversity. Life, Sustainability and Equity. Orient Longman, New Delhi.

KRISHNAGOPAL, G. &. SIMMONS, R. (2007): Urban and Periurban Agriculture: Towards better Understanding of low Income Producer Organizations. Hyderabad City Case Study. Access Livelihoods Consulting India Private Limited, Secunderabad and International Water Management Institute (IWMI), South Asia Regional Office, Patancheru, India.

MARTIN, G. (2004): Ethnobotany. A Methods Manual. People and plants conservation series, Earthscan, London (first published in 1995).

MAYRING, P. (2007): Qualitative Inhaltsanalyse: Beltz UTB., 9. Auflage, Weinheim.

MILLSTONE, E. & LANG, T. (2008): The Atlas of Food –Who eats what, where and why. 2nd edition, Earthscan, London.

MÜHLENBERG, M. (1993): Freilandökologie. Quelle und Mayer, 3., überarb. Aufl., Heidelberg.

MURALI, K. (2002): Food Insecurity Atlas of Urban India. M.S. Swaminathan Research Foundation, Chennai.

PATEL, A. (2003): Using City Compost for Urban Farming in India. In: Urban Agriculture Magazine no. 9, RUAF Foundation, pp.37-38.

PEET, R. (1974): The Measurement of Species Diversity. In: Annual Review of Ecology and Systematics, vol. 5, pp. 285-307.

PURSEGLOVE, J. W. (1974): Tropical Crops - Dicotyledons. Longman Scientific & Technical, Harlow.

QUIROZ, C. (1996): Local knowledge systems contribute to sustainable development. In: Indigenous Knowledge and Development Monitor Newsletter. Available at: http://nird.ap.nic.in/clic/rrdl73.html.

RAMANJANEEYULU, D. & CHENNAMANENI, R. (2007): Pesticides, Residues and Regulation – A Case of Vegetables in Hyderabad Market. Centre for Sustainable Agriculture (CSA), Secunderabad.

RASCHID-SALLY, L. & JAYACODY, P. (2008): Drivers and characteristics of wastewater agriculture in developing countries -results from a global assessment. IWMI Research Report World Water Week, Stockholm.

REYES-GARCIA, V., VADEZ, V., MARTI, N., HUANCA, T., LEONARD, W. & TANNER, S. (2008): Ethnobotanical knowledge and crop diversity in swidden fields: A study in a native Amazonian society. Springer science, published online: http://people.brandeis.edu/~rgodoy/publications/szoDB.tmp.pdf.

RICHTER, C. (2005): Agrikulturchemie und Pflanzenernährung. Margraf, Weikersheim.

SAYDEE, G. & UYEREH, S. (2003): Appropriate (Micro-) Technologies for Urban Agriculture. In: Urban Agriculture Magazine no. 10, RUAF Foundation, pp.16-17.

SCOTT, C., FARUQUI, N. & RASCHID-SALLY, L. (ed., 2004): Wastewater Use in Irrigated Agriculture - Confronting the Livelihood and Environmental Realities. Cabi International in association with IDRC and IWMI, Ottawa, Colombo.

SEN, A. (1999): Poverty and famines. An essay on entitlement and deprivation. Oxford Univ. Press. First published in 1981, Delhi.

SHANNON, C. & WEAVER, W. (1963): The mathematical theory of communication. University of Illinois Press.

SHIVA, V. (2000): Biodiversity. Social and Ecological Perspectives. New Delhi.

SHIVA, V. &. PANDEY, P. (2006): Biodiversity based Organic Farming. A new Paradigm for Food Security and Food Safety. New Delhi.

SIMPSON, E. (1949): Measurement of Diversity. In: Nature vol. 163, London, p. 688.

SMALE, M. (ed.) (2007): Valuing Crop Biodiversity. On-farm genetic resources and economic change. CABI Publications, Wallingford, UK.

SMIT, J. (2000): Urban Agriculture and Biodiversity. In: Urban Agriculture Magazine no 1, RUAF Foundation, pp. 11-1

SØRENSEN, T. (1948): A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Biologiske Skrifter / Kongelige Danske Videnskabernes Selskab.

THRUPP, L. (2003): Agricultural Biodiversity: A Key Element of Ecosystem Health and Sustainable Food Security. In: RAPPORT et al (ed.): Managing for Healthy Ecosystems. Lewis Publishers, US. pp. 317-333.

TINDALL, H. (1983): Vegetables in the Tropics. Macmillan (Macmillan international college edition), London.

UNEP-UNCTAD (2008): Organic Agriculture and Food Security in Africa. UNEP-UNCTAD Capacity Building Task Force on Trade, Environment and Development. United Nations Conference on Trade and Development, United Nations Environment Programme, New York, Geneva.

UN-HABITAT (2007): Enhancing Urban Safety and Security – Global Report on Human Settlements 2007. United Nations Human Settlements Programme. Earthscan, London.

UN-HABITAT (2008): State of the World's Cities 2008/09. Harmonious Cities. Available at: http://www.unhabitat.org/content.asp?cid=5964&catid=7&typeid=46&subMenuId=0.

VAN DER HOEK, V., HASSAN, U., ENSINK, J., FEENSTRA, S., RASCHID-SALLY, L., MUNIR, S., ASLAM, R., HUSSAIN, R. & MATSUNG, Y. (2002): Urban wastewater: A valuable resource for agriculture. A case study from Haroonabad, Pakistan. Research Report 63. International Water Management Institute, Colombo, Sri Lanka.

VAN ROOIJEN, D., TURRAL, H. & BIGGS, T. (2005): Sponge City. Water Balance of Mega-City Water Use and Wastewater Use in Hyderabad, India. In: Irrigation and Drainage vol. 54, pp. 81-91.

WHO (2002): The World Health Report 2002: Reducing Risks, Promoting Healthy Life, Geneva.

WHO (2003a): Diet, Nutrition and the Prevention of Chronical Diseases. (WHO Technical Report Series, 916), Geneva.

WHO (2003b): Fruit and Vegetable Promotion Initiative. A Meeting Report, Geneva.

WHO 2006: Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Vol. 1, Policy and Regulatory Aspects, Geneva.

YASMEEN, G. (2001): Urban Agriculture in India: A Survey of Expertise, Capacities and Recent Experience. A Study Commissioned by: International Development Research Centre South Asia Regional Office, New Delhi.

Internet

Andhra Pradesh Department of Agriculture (DOA) http://www.aponline.gov.in, accessed: 25. 4. 2009

Andhra Pradesh Department of Horticulture (DOH) http://www.aphorticulture.com/, accessed: 28. 4. 2009

Andhra Pradesh Directorate of Economics and Statistics http://www.apdes.ap.gov.in/, accessed: 10. 4. 2009

BBC: http://www.bbc.co.uk/weather/world/city_guides/results.shtml?tt=TT002250, accessed: 28. 4. 2009

BiodiversityPro: http://www.sams.ac.uk/research/software, accessed: 8. 4. 2009

CIA-Maps: http://www.globalsecurity.org/wmd/world/india/images/cia-map_india.jpg, accessed: 28. 4. 2009

City Mayors Statistics: http://www.citymayors.com/statistics/urban_2006_1.html, accessed: 10. 4. 2009

Cityfarmer: http://www.cityfarmer.org/subsouthasia.html, accessed: 16. 4. 2009

Consultative Group on International Agricultural Research (CGIAR): http://www.cgiar.org/, accessed: 3. 4. 2009

Convention on Biological Diversity, Conference of the Parties (COP): www.cbd.int, accessed: 25. 4. 2009

Crop Diversity Trust: http://www.croptrust.org/main/, accessed: 10. 5. 2009

Directorate of Economics and Statistics, Government of Andhra Pradesh: http://www.apdes.ap.gov.in/

EAWAG (ETH Zürich): http://www.eawag.ch/index, accessed: 15. 4. 2009

European Partnership for Fruits Vegetables and Better Health: http://epbh.org/index.shtml, accessed: 11. 4. 2009

European Union Law (Official Journal of the European Union, Commission Decision):
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:255:0040:0041:EN:PDF

FAO: http://www.fao.org/docrep/x0560e/x0560e05.htm, accessed: 10. 5. 2009

FAOSTAT: http://www.fao.org/faostat/foodsecurity/index_en.htm, accessed: 15. 4. 2009

Food Plants International, Australia: http://www.foodplantsinternational.com, accessed: 30. 4. 2009

Forum for a Better Hyderabad http://www.hyderabadgreens.org/musi.html, accessed: 14. 4. 2009

Global Facilitation Unit for Underutilized Species:
http://www.underutilized-species.org/institutional_mapping/about_im.asp, accessed: 15. 4. 2009

Horticulture Cultivars Performance Database (Hortivar) http://www.fao.org/hortivar/survey.htm, accessed: 17. 4. 2009

Hyderabad Metropolitan Water Supply & Sewerage Board: http://www.hyderabadwater.gov.in/wworks/, accessed: 16. 5. 2009

Hyderabad Urban Development Authority (HUDA) http://www.hudahyd.org, accessed: 10. 4. 2009

Indian Institute of Horticultural Research http://www.iihr.res.in/, accessed: 12. 4. 2009

International Association for Plant Taxonomy http://www.botanik.univie.ac.at, accessed: 26. 4. 2009

International Fruit and Vegetables Alliance: http://www.ifava.org/, accessed; 11. 4. 2009

International Plant Genetics Resources Institute/Bioversity International: http://www.bioversityinternational.org/, accessed 7. 4. 2009

IDRC-UPE Programme: http://www.idrc.ca/uploads/user-S/11866841271UPE_Prospectus_2005-2010_-_Public.pdf, accessed: 28. 4. 2009

MAXQDA: http://www.maxqda.com/, accessed: 15. 4. 2009

Medinidia: http://www.medindia.com, accessed 6. 4. 2009

Millennium Dvelopment Goals: http://www.un.org/millenniumgoals/, accessed 7. 4. 2009

Millennium Development Goals Monitor: http://www.mdgmonitor.org/, accessed 7. 4. 2009

RUAF Homepage : www.ruaf.org, accessed: 10. 4. 2009

Suedasien-Info: http://www.suedasien.info/laenderinfos/461, accessed: 12. 5. 2009

The Hindu: http://www.hinduonnet.com/, accessed 12. 5. 2009

Urban Agriculture Magazine: Urban Agriculture Magazine, the RUAF Foundation: http://www.ruaf.org/index.php?q=node/101, accessed: 19. 4. 2009

US Department of Health and Human Services: http://www.hhs.gov/, accessed: 11. 4. 2009

WHO statistics: http://www.who.int/diabetes/facts/en/diabcare0504.pdf. accessed: 6. 4. 2009

World Food Summit 1996: http://www.fao.org/wfs/index_en.htm, accessed 10. 4. 2009

Annexe

Annexe I: List of the vegetables identified in the research area

Telugu/Local Name	English Name	Botanical Name	Family
Palak	Spinach	Spinacea oleracea (L.)	Amaranthaceae
Thotakura	Amaranth, green	Amaranthus tricolor (L.)	Amaranthaceae
Koyakura	Amaranth, red	Amaranthus tricolor (L.), red variety	Amaranthaceae
Chukkakura	Bladder Dock	Rumex vesicarius (L.)	Polygonaceae
Bacchalikura	Malabar Spinach	Basella alba var. rubra (Moq.)	Basellaceae
Gongura	Roselle	Hibiscus acetosella (Welw.) red, H. sabdariffa (L.), green	Malvaceae
Soyakura	Dill	Anethum graveolens (L.)	Apiaceae
Kothimira	Coriander	Coriandrum sativum (L.)	Apiaceae
Pudina	Mint	Mentha sp.	Lamiaceae
Gangavallikura	Common Purslane	Portulaca oleracea (L.)	Portulaceaceae
Menthikura	Fenugreek leaves	Trigonella foenum-graecum (L.)	Fabaceae
Pulichintakura	Creeping Woodsorrel	Oxalis corniculata (L.)	Oxalidaceae
Ponnagantikura	Dwarf Copperleaf	Alternanthera sessilis	Amaranthaceae
Gourmentkura		Althernanthera sp.	Amaranthaceae
Chamakura	Colocasia	Colocasia esculenta (L.)	Araceae
Kurvepaku	Curry Leaves	Murraya koenigii (L.)	Rutaceae
Chennangi	Chennangi	Lagerstroemia parviflora (Roxb.)	Lythraceae
Moramgadda	Maniok/Tapioca/Cassava	Manihot esculenta (Crantz.)	Euphorbiaceae
Ratnapurigadda	Sweet Potato	Ipomoea batatas (L.)	Convolvulaceae
Bhindi	Lady's finger	Abelmoschus esculentus (L.)	Malvaceae
Mirapakayalu/Mirchi	Chili	Capsicum frutescens (L.)	Solanaceae
Mirapakaya	Capsicum	Capsicum annuum (L.)	Solanaceae
Vankaya/Brinjal	Aubergine	Solanum melongena (L.)	Solanaceae
Tomato	Tomato	Lycopersicon esculentum (M.)	Solanaceae
Carrot	Carrot	Daucus carota (L.)	Apiaceae
Beetroot	Beetroot	Beta vulgaris (L.)	Amaranthaceae
Radish	Radish	Raphanus sativus (L.)	Brassicaceae
Gobi Gadda	Cabbage	Brassica oleracea var. capitals (L.)	Brassicaceae
Gobipuvu	Cauliflower	Brassica oleracea var. botrytis (L.)	Brassicaceae
Ullipaya	Onion	Allium cepa (L.)	Liliaceae
Velluli Payalu	Garlic	Allium sativum (L.)	Liliaceae
Allam	Ginger	Zingiber officinale (Rosc.)	Zingiberaceae
Kakava Kaya	Bitter Gourd	Momordica charantia (L.)	Cucurbitaceae
Adavikakava	Wild Bitter Gourd	Momordica sp.	Cucurbitaceae
Sora Kaya	Bottle Gourd/Calabash	Lagenaria siceraria (Molina)	Cucurbitaceae
Beera Kaya	Ridged Gourd	Luffa acutangula (L.)	Cucurbitaceae

Potla Kaya	Snake Gourd	Trichosanthes cucumerina (L.)	Cucurbitaceae
Dosa Kaya	Cucumber	Cucumis sativus (L.)	Cucurbitaceae
Adavikandulu	Pumpkin/Butternut Squash	Cucurbita moschata (Duch.)	Cucurbitaceae
Gummadi Kaya	Ash Gourd/Wax Gourd	Benincasa hispida (Thunb.)	Cucurbitaceae
Donda Kaya	Ivy Gourd	Coccinia grandis (L.)	Cucurbitaceae
Palli	Groundnut	Arachis hypogaea (L.)	Fabaceae
Beans	French Bean	Phaseolus vulgaris (L.)	Fabaceae
Goruchikkudu	Cluster Bean	Cyamopsis tetragonoloba (L.)	Fabaceae
Pesar Pappu	Green Gram/Mung Bean	Vigna radiata (L.)	Fabaceae
Kandi Pappu	Red Gram/Pigeon pea	Cajanus indicus/cajan (L.)	Fabaceae
Minapa Pappu	Black Gram	Vigna mungo (L.)	Fabaceae
Pappu	Lentil	Lens culinaris (Medik.)	Fabaceae
Batanilu	Green Pea	Pisum sativum (L.)	Fabaceae
Bebbarlu	Cow Pea	Vigna unguiculata (L.)	Fabaceae
Turmeric	Kurkuma	Curcuma domestica (Val.)	Zingiberaceae
Munagakaya	Drumstick/Benoil Tree	Moringa oleifera (Lam.)	Moringaceae
Chintapandu	Tamarind tree	Tamarindus indica (L.)	Fabaceae

Annexe II: Questionnaire (semi-structured interview)

Date:________ Time:________ Interview Nr. ____ WP No:_____ Garden ID:________

Village______________________

Purpose: Study on crop diversity for Master's programme

Declaration: Participants of the interviews will take part on a voluntary basis and not be paid. There will be no pressure to answer and they can refuse to answer any questions. No personal information will be published.

1. Interviewee: □male □ female Name:_______________________

Total area cultivated_______By how many people?__________ Family? __________

How many years have you been growing Vegetables here? ________________

2. List of the vegetables you grow (fill in Matrix)

When are they grown during the year? (fill in Matrix)

<u>Growing purpose and usage</u>:

3. Is there any plant only grown for self-consumption and if yes, what?________________
Is there any plant only grown for sale and if yes, what?______________________________

Decision making:

4. Why do you grow so many different vegetables, why not only one or two? ____

(If leafy veg garden): Why do you grow so many leafy vegetables and not for example cabbage, brinjal, tomato etc.? ____

5. Who decides what to grow?____
What influences the decision?____
____

Underline what influences your decisions:

Market? Crop rotation? Tradition? What neighbours grow?
Land tenure? Water quality? Seed availability?
Input costs? Spreading Risk?

What is the most important? What is least important?

Input:

6. Where do you get the seeds from?（fill in Matrix)
How many cuts do you get from one package?（fill in Matrix)
How many days does it take from sowing to harvesting?（fill in Matrix)
Are there seeds that you can by only at certain times or can you buy everything you want all year round?____

7. How much did you spend last month for seeds, fertilizer, pesticides? __________
What was your income?___________________________________
How often do you buy fertilizer and pesticides?_________________________
Is there any vegetable that needs more or less fertilizer that another? If yes, what?

Have there been any changes in fertilizer costs or availability in the last months?
Do you also use manure or compost? Where do you get it from?

Irrigation:

8. Is the water good for cropping? Is there anything good about the water? What? Why? Is there also anything bad? In what way?

____

____

Local agricultural knowledge:

9. Were your parents also farmers? □ yes □ no

How did you learn to cultivate these plants? Where do you learn new things?

____

Sources that play a role(underline): Familiy? Neighbours? Trial?

Agricultural extension services? Land owner?

Which is most important? Which is least important?

Since when have you been growing which vegetable? (fill in Matrix)

Since you have been growing vegetables, which did you add, which did you abandon?

Plant rotation: Is there a vegetable that you should/cannot grow after another vegetable? Which vegetables can be intercropped? Which cannot?

Land tenure:

10. Is the land □owned by you/relative □ leased □ other________________________________

Price? ______________________For how long (Month/Year)?__________________________

Do you expect to lease the garden next year also?_______________________________________

If you were the land owner, would you grow the same? □ yes □ no

If no, what?____

why?____

Working situation:

11. Are you working here □ all year □ seasonal _____________________________________

How many days per week?_________________ How many hours per day?_________________

Is vegetables farming your only occupation?____

Is there another income source to the household? □ yes □ no/what?_____________________

You income on a good day______________on a bad day________________________________

Sociostatistical information:

12. How old are you/when were you born? ____________

Have you attended school? □ yes □ no

Up to which level? ____

What is your place of birth? □Hyderabad □other__________________________________

When did you arrive here? Why did you come here?__________________________________

Caste/ Religious affiliation:

Any additional information:

Matrix :

List of vegetables	Grown all year? (In which season)?	Since when grown?	Hybrid seeds? Since when?	Seeds from where? Price?	How many cuts/package?	How many days from sowing to harvest?

Annexe III: Statistics

Is the diversity and composition of vegetable varieties significantly different comparing groundwater and wastewater-irrigated gardens referring to the area?

T-test of the two diversity index results (Shannon index, calculated with BioDiversity Pro):

Sample	Mean Individuals	Variance	Standard Deviation	Total Species
GW	31308.703	5582547968	74716.45	21
WW	289119.094	4.2^{11}	650330.428	16

Hs1 (groundwater) = 1.75

Hs 2 (wastewater) = 1.71

A T-test of two index values can be calculated if the variance of is known (MÜHLENBERG 1993, pp. 352-353):

$$\text{Var}(H_S) = \frac{\sum_{i=1}^{S} p_i (\ln p_i)^2 - (H_S)^2}{N} + \frac{S-1}{2N^2}$$

The degrees of freedom are calculated as follows:

$$df = \frac{(\text{Var}\, H_1 + \text{Var}\, H_2)^2}{\frac{(\text{Var}\, H_1)^2}{N_1} + \frac{(\text{Var}\, H_2)^2}{N_2}}$$

df = 1188.9

$$t = \frac{|H_1 - H_2|}{\sqrt{\text{Var}(H_1) + \text{Var}(H_2)}}$$

$t = 5.27^{-4}$

t*(1188.9; 0.05) = 1.961

t < t*

Result: There is no significant difference in species diversity between wastewater and groundwater-irrigated vegetable gardens.

<u>T-Test of the two samples of varieties in wastewater and groundwater-irrigated gardens (cf. BAHRENBERG & GIESE 1975):</u>

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

H0 : μ1 = μ2

FG = (n1-1) + (n2-1) = 35, α = 0.05   n1 = 16,   n2 = 21

t* 0.05 (2), 35= 2.03   x1 = 941,   x2 = 230.9   (mean)

t = 2.36   s1 = 1315.4   s2 = 368.7 (standard deviation)

t > t*

Result: μ1 ≠ μ2, the two samples differ from each other significantly in the composition of vegetable varieties.

Correlations between the number of vegetable varieities and other factors:

Varieties/Age: **r = 0.34**; non-significant positive correlation

Varieties/Experience: **r = 0.63; significant positive correlation**

Varieties/ Agricultural knowledge**: r = 0.38; significant positive correlation**

Varieties/Gender: **r = - 0.18** (M = 0; F = 1) non-significant negative correlation

Varieties/ Size of the cultivated area: **r = 0.49 significant positive correlation**

Varieties/Years of school attendance: **r = 0.37 significant positive correlation**

Critical value for r with a=0.05 with Df = 28 (n-2): **0.36**