Towards assessing the metabolism of the Gauteng City-Region

Biomass flows scoping paper

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1. INTRODUCTION

This study is part of a broader research project towards understanding and assessing the metabolism of the Gauteng City-Region for the flows of energy, water and sanitation, biomass (food and non-food) and waste (GCRO, 2011). The wider objective of this research is to provide a pragmatic approach to describe and analyse these urban metabolic profiles and in doing so, derive insights for more sustainable urban planning and infrastructure.

While most studies of urban metabolism have been purley accounting exercises and measures of physical flows (Kennedy, 2010: 1065), there is also a need to learn about the underlying drivers of resource use and to link the material composition of cities to socio-economic factors, infrastructue patterns and planning structures (Krausmann et al, 2009). Therefore, while it is important to elucidate physical inflows and outflows within cities, it is also critical to gain a better understanding of *how* these flows can be transformed for sustainability (Barles, 2009, 899).

This specific focus of this paper is a preliminary investigation into Gauteng City-Region (GCR)'s biomass metabolism, which operates in parallel to number of equally relevant urban metabolisms. This specific focus of this paper is to identify the data required to account for biomass flows within the GCR and to understand the underlying socio-economic, spatial and infrastructural determinants of these flows.

An overview of studies thus far shows partiality to study the food flow components of biomass or what Stefen Wirsenius (2003: 48) has termed "the biomass metabolism of the food system". This is for good reason. The most essential use of biomass is the provision of food for humans and feed for animals and as numerous studies show, food chains and systems continue to represent the largest total consumption of biomass across the globe (Ayres in Krausmann et al, 2008: 472; Weighell, 2011: 2). Studies of 'food flows' have also stemmed from due concerns about the affects of urban population pressure on food demand and land resources and urban dependences on rural agriculture that results in extensive cropping and high food imports (Dreschel et al, 2007: v).

In addition to the flows within food systems, there are a number of biomass metabolisms within non-food systems, to extend Wirsenius's insight, that ought to be considered in a comprehensive urban metabolism assessment. These include those within vegetation, land and other plant-based biological matter used for non-food purposes, such as for fuel, conservation or horticultural use. Inclusion of these biomass stocks can stretch our discussion to think about the broader landscape that supports current resource use, but in doing so, creates additional data requirements and important primary data developments (Minx et al, 2010: 7). These need to be weighed up against the time, scope and financial limitations of Phase I of this research project, and it may not be feasible to study all aspects of the GCR's biomass metabolism at this stage.

In light of the above, this report echoes the recommendation of the Stockholm Resilience Centre (Minx et al, 2010: 8: 66), to focus on specific aspects of the biomass metabolism and give priority attention to data that is either publicly available and data situations that are more developed and reliable (UNEP, 2011: 8). The suggested starting point for data collection is to focus on *food* biomass flows and the various flows within agri-systems relevant to the GCR context. If it emerges during Phase II that sets of data, yielding insights and analyses about non-food biomass, can be accessed within scope, time and financial margins, work can be broadened to include these datastreams. In the interim, however, it is suggested that data collection during Phase I of this project needs to provide insights into the following:

A. Estimates of the physcial magnitude of food biomass flows
B. The physical and institutional configuration of infrastructure networks channelling and delivering food flows
C. The interface between political economic factors and configuration of regional food infrastructure
D. The affect of agri-food systems on peoples' access to food and the distribution of food flows
E. The interaction between food flows and other components of the urban metabolism

In doing so, this report makes aims to contribute to the overarching aim of understanding the GCR's urban metabolism and identify the data required to make concrete recoomendations about what is unsustainable within this metabolism. The scope of the study is set using the Gauteng Province official administrative boundary. This is the unit of analysis for the first phase of research, which will be expanded in a second phase that includes both the Gauteng Province and the urban nodes of the wider city-region.

To achieve the above, the paper progresses in four steps. First, as part of our introduction, we present the concept of biomass within an urban context to contextualise our study and its analytical logic. The methodological parameters guiding the broader research are summarised in Annexure A to open the immediate discussion to the latent social and infrastructural processes of biomass flows in the urban metabolism of the GCR. These are covered by the second step, which gives an overview is given of the constituents affecting biomass flows in Gauteng, including institutional arrangements, classification approaches, physical infrastructure, resource users and the drivers of biomass flows. Upon describing these components, our third step is to identify the data sources necessary to execute a biomass flow assessment given relevant issues. Finally, recommendations are made on how a biomass data collection exercise for Gauteng should proceed.

Biomass in the urban metabolism

Biomass is the sum of recent, non-fossil organic material of biological origin, and as such, is one of the fundamental resources of any socioeconomic systems (Krausmann et al, 2008: 472). Krausmann et al (2008: 472) further explain the pivotal role of understanding biomass flows, which are intimately linked to the global biogeochemcial

cycles of carbon, nitrogen, phospherous and other substances, and to the flow of trophic energy in ecosystems.

Human use and appropriation of biomass is reaching unprecendented levels. This is through the increasing extraction, import and production of biomass for activites such as human and animal food production, wood-based products and textiles, and various industrial processes (Weisz et al, 2005: 10|). Biomass production for these purposes is creating major pressures on biodiversity due to deforestation, fertilizer and pesticide application, groundwater depletion and ecosystem depletion (Chabra in Krausmann et al, 2008: 472). Critically, rapid growth in the volume of biomass trrade is resulting in a surging spatial disconnect between the places where biomass is consumed and the places where environmental impacts occur (Erb et al, 2009: 328).

Understanding the spaces of biomass flows necessarily draws attention to urban contexts and the implications of urban growth patterns on biomass use. This is because of the material and resource flows induced by urban regions, due to high population densities and large material stocks, which result in high urban metabolic rates (Hendriks et al, 2000: 312). The resulting spatial disconnect between the location of biomass production and consumption calls for research taking into acconut of the regional characteristics of land use systems and biomass use patterns such as those manifesting through urban processes (Krausmann et al, 2008: 472).

Although the application of general metabolism studies to urban environments has gained momentum (see Erb et al, 2009: 329; UNEP: 2011: 8; Krausmann et al, 2008), such studies exist at a generalised, global scale, or typically for greater metropolitan areas and in developed nations (Kennedy et al, 2007; UNEP, 2011: 8). The limited number of biomass flow assessments at a refined, urban scale, is also the case for Gauteng and its urban nodes, which are generally lacking a long-term database for trend analysis on resource flows and indicators and how these flows interact with other critical development statistics (Weighell, 2011: 4).

Making inroads into this type of data collection therefore involves an audit of available data sets that can provide insights into physical flows as well as the intricate web of regional institutional infrastructure that make up the circuits of urban landscapes, an important conceptual frame underpinning our data collection efforts (Swyngedouw & Heynen, 2004: 906).

2. OVERVIEW OF INSTITUTIONAL ARRANGEMENTS – preliminary reflections on the institutional infrastructure of food systems

The configuration of lines of connections and access nodes for networks, as well as user charges and service packages, becomes geared within 'markets' to the needs of particular users and spaces, rather than being driven by broader, public notions of cross subsidization and the imperative of serving entire urban territories

(Graham, 2000:188)

The work of Stephen Graham moves discussions about urban metabolisms towards exploring the social production of infrastructure. This is crucial since infrastructure networks are ingrained in social processes that give resource flows a deeply political nature, often customized to the benefit of certain needs and users. An examination of these dynamics, as major fatures of resource systems, can cast light on the processes in which infrastructure networks are embedded, and often entrenched, as well as the politics of resource systems. Doing so is an attempt to address the tendency of technocratic, apolitical accounts of infrastructure networks to neglect deeply political issues such as the persistent inequalities of service provision (McFarlane & Rutherford, 2008: 364). This kind of thinking also illuminates the political geographies of urban infrastructure and the various spatial scales at which socio-metabolic patterns are produced, undone and reproduced through political struggle (Marvin & Medd, 2006: 317; Krausmann et al, 2009: Brown & Purcel, 2005: 607).

The research challenge lies in recognising the whole biomass chain (Erb et al, 2009: 329) as this calls for a harmonised data collection effort that focuses both on the physical flows biomass and the underlying institutional infrastructure of food system (Bartlett in Rapoport, 2011: 5). This is because the composition of a food supply systems[1] is inherently complex and in addition to formal institutional arrangements (summarised in Table 1), there are intricate webs of production, processing, distribution, sale and consumption processes that make up complex infrastructural circuits of food metabolisms (Rudolph et al, 2012; GCRO, 2010: 42). This dynamism, briefly reflected upon below, coupled with factors such as climate change, rapid land use shifts and the effects of political economic change on poorer producers and consumers, render static assumptions of, and research into, stable and one-dimensional systems inadequate (Thompson et al, 2004: 3). While a focus on the generalizable components of food chains (Figure 1) will be maintained, this paper argues for a data collection exercise that provides sufficient insight into the dynamic and complex character of agri-food systems to enhance the capacity of such systems to adapt to change (Thompson et al, 2004: 3).

If consideration of dynamism in the argi-food is important, the significant restructuing within the food chain of developing countries over recent decases is a central research theme (Mather, 2005a: 608, Mathew, 2005b). Various factors, inter alia, population growth, income changes and urbanisation, have stimulated demand for food and certain types of food, particularly processed and meat-based meals, and a growing dependency on rural food production to supply growing urban appetites (Thibert et al, 2011: 1814; Mather, 2005: 608-609). These socio-economic trends have seen demand for food in Gauteng continue unabated and food consumption dominanted by cereals and meat, compared to intakes of fresh fruit and vegetables, and by imported foods:

> *Gauteng is currently consuming far more food than it is producing and is therefore heavily dependent on imported food produce…. a total of*

[1] For the purposes of our study, the focus is on dynamics relating to food and agri-systems.

618,000 tons of food are produced per annum in Gauteng in comparison with 5,193,260 tons of total food consumed (GCRO, 2010)

A noticable trend also observed in other parts of the world is that urban demand for food in Gauteng is increasingly met through large supermarket chains who dominate the agrifood sector and essentially control of food sales (Mather, 2005: 608-609; Weathersppon & Reardon, 2003: 332; Mind Shift, 2008). This process is otherwise described as agroindustrialisation, which has seen the growing concentration and expansion of retailing and foreign direct investment (FDI) in the food processing sector generally (Mather, 2005b). This has had significant social, political economic and poltical ecological implications due to the underlying agro-industrial model of the 'green revoltuion' that has underpinned world agricultural production since the 1950s. The 'green revolution' is the type of agriculture that ensued after World War II which stimulated a drive for research from the armaments industry in various potent chemicals such as DDT and chlorine and phosphorous compounds (The Royal Society, 2009; 2; Ashton, 2008). The green revolution fundamentally affected the global food production system which experienced a near tripling of the world irrigated area, a 10-fold growth in world fertilizer use, and the rapid dissemination of high-yielding varieties (Brown, 2008; 36).

On the one hand, the two to threefold increases in global food production in the last 50 years have been viewed by as fundamental to meeting the needs of a world population that in 2007 stood at an unprecedented 6 billion, of which 840 million are hungry (Doran, Kirschenmann & Magdoff, 2007; 77). Proponents further see the high yielding plant and animal varieties, mechanized tillage, synthetic fertilizers and chemical inputs based on fossil fuels, and transgenic crops, as part of the stunning technological achievements of the 'green revolution' that are essential to produce food for the world's growing population (Badgely *et al*, 2007; 86). However, this obscures the long-term effects of high-external input (HEI) agri-indstustrial systems reliant on genetically modified seed, fertilizers, pesticides, and heavily water-, energy-, and capital- intensive types (Pretty *et al,* 1995; 129). The underlying geopolitics of these issues, such as the terms of globalization and biased OECD subsidy regimes, places the politics of food and who benefits from emergin geopolitics, as questions that warranting more detailed analysis in relation to Gauteng (Thompson et al, 2007: 48). As previous GCRO research summarized:

"The well-documented impacts of the industrialised and unregulated nature of the modern food system include environmental degradation, climate change, high dependency on fossil fuels, marginalisation of small farmers and high levels of food insecurity linked to unfair global trade" (GCRO, 2010: 42)

At the same time, while large scale retailers generally dominate markets due to their competitive and price advantage, there are also less formal nodes and networks that channel food flows (Crush et al, 2011: 300). The informal economy is an important source of food for poorer households in South African cities, with street vendors, cornr stores and other small-scale operators and micro-entreprensurs operating alongside supermarket chains (Rudolph et al, 2010: Martins, 2006: 18; Frayne et al, 2010). For instance, Rudolph et al (2012) found that more than 70% of households in

Johannebsurg source food from informal markets or roadside stalls at least once a week or even more often. In this regard, the authors further note the following:

> *"…the preference for foods sources from informal vendors may be linked to high levels of mobility and long-distance commuting within the city, to the difficulty and cost of transporting large volumes of food from supermarkets, and to inadequate cold storage in households which may not have fridges or electricity and the ability to pay for electricity" (Rudolph et al, 2012).*

These food change also have disticnt socio-spatial dynamics in Gauteng. On the one hand, although supermarket chains are often associated with urban middle-class, these food outlets are also increasingly important sources of food for poorer households due to convenience and price comparisons to other options (Rudolph et al (2012). Retail food outlets are also patronised more requently in certain areas, such the Inner City, and least often in more rural areas, such a Orange Farm due to socio-economic reaonss (Rudolph, 2012). Areas on the outskirts of cities are also those that generally pursue some type of farming and food production and as found in a recent study, 89 percent of households in Orange Farm engaged in urban farming but also had no household members in formal employment (Crush et al, 2011: 289). These trends have been also been summarized for Johannesburg where:

> *Only 9% of households surveyed actually grow some of their own food, although the proportion is higher in peri-urban areas (16%) than townships (8%), and the inner city (2%) where land is less available. (Warshawsky, 2011: 18)*

Additional actors in the food value chain are the municipal fresh produce markets that function as critical intermediaries between producers, distributers and retail actors in major metropoles such as Johannesburg, Tshwane and Ekurhuleni. These mediators of food flow transactions and processes, between rural food production on the one hand, and urban or even peri-urban consumption on the other, give that is predominantly urban, give the urban food ageda particlar dynamics and crossscale linkages that need to be considered in understanding the dimensions of urban food security (Crush et al, 2011: 539). Beyond facilitating the flow of food coming into Gauteng towards, municipal 'food' entities, as such, have also assumed an interesting position in relation to food security concerns. For instance, the Johannesburg Foodbank is a relief hunger organisations run out of the Johannesburg Fresh Produce Market since 2006 (subsequently renamed the Joburg Market) while the Tshwane FoodBank Depot has been a facility at the Tshwane Fresh Produce Market since 2010 (Warshawsky, 2011: 13-14). These trends lend themselves to a series of enquiries about the role of municipal governments, and city-specific food security programmes, (Crush et al, 2011: 54), that in-turn align to local produce and landscapes, in securing more sustainable food flows in Gauteng.

Research into Gauteng's complex agri-food system, and its underlying institutional architecture, also needs to provide evidence of how a budding urban food garden and organic movement in South Africa is playing out in Gauteng more specifically. The roots of this trend appear to be a growing ecological, social and health conciousness

about the long-term effects of unsustainable food chains (Niemayer et al, 2003). While this remains a niche market, community gardens such as the Siyakhana Permaculture Garden in Bezuidenhout Park are using agro-ecological methods as a holistic approaches to urban food prodcution and to address nutrituional and economic needs (Siyakhana, 2011). Parallel to this, is the emergence of local-, community-run- food markets, such as the Neighbourgoods Market in Johannesburg or the Irene Market in Tshwane, as alternatives to retailers, and sale organic products both in supermarkets and in less formal environments. The Institute of Natural Resources (IRN) (IRN, 2008: 12) observes that the organic movement in South Africa at large has grown from small informal groups producing organic products to what some have observed as a rapidly growing and more formalised sector (IRN, 2008: 12).

This necessitates detailed research into Gauteng's experience of the organic food movement and what is facilitating or hampering this trend. Preliminary research shows that in addition to Cape Town and Durban, Gauteng is a main centre of organic consumption (Barrow in IRN, 2008: 79). However, these observations need to be disaggregated into the types of consumers currently benefitting, how this breaks down per Living Standard Measure (LSM) bracket and in relation to wider institutional dynamics. Interestingly, while 'supermarketization' has received bad press, major players such as Massmart, Pick 'n Pay and Woolworths, have initiatied important developments in support of more sustainable food chains, such as sustainability audits on their produce; packaging and waste reduction solutions; and environmentally-conscious labelling (Mind Shift, 2007). Tracing these shifts is important insofar as to identify solutions to food innovation bottlenecks, uncompetitive prices for organic products that undermine a robust domestic organic food sector in South Africa at large (Niemayer & Lombard, 2003: 9).

The above features represent a taste of the highly differential, and often fluid nature of food flows. Data collection for our study needs to reflect in more on detail these complex dynamics in order to provide evidence on how and why food flows the way it does. The research implication is that detailed evidence is needed on the relationships and interplay between food production, distribution and consumption systems, and that this evidence needs to help us understand how this complexity pays out in Gauteng. Importantly, this research needs to yield alternative insights to the simplicity of 'rural development' and 'green revolutions' promoted since 1994 to address food security and small-scale production (Crush et al, 2011: 528; GCRO, 2010: 43), in that it includes a suite of different actors that, as a collective, play a role in sustaining food flows.

3. CLASSIFICATION OF THE SPECIFIC METABOLIC FLOWS

The three broad methodological approaches guiding this study have specific applications to, and definitions of, biomass. However, the use of these together (described below in their individual applications), lend our study to propose a new classification systen.

3.1 Economy-wide Material Flow Anlaysis

According to Economy-wide Material Flow Analyisis (EWMFA), material inputs are distinguised according to the two major pathways entering society (Schulz, 2005: 15):

- Material extracted from the domestic environment and;
- Traded materials (Imports and Exports) originating from- or being sent to - the rest of the world (ROW)

The Eurostat (2001) classification further distinguishes resource flows acording to two major pathways, the *material input side* and the *material output side* the of an economy-wide MFA. It follows that biomass as a *material input* can be an input from the natural environment into the economy, to be accounted for as **used or unused**[2] **"domestic extraction"** (Eurostat, 2009: 12). Domestic extraction (DE) of biomass includes all biomass of vegetable origin extracted by humans and their lviestock, fish capture, and the biomass of hunted animals (Eurostat, 2009: 24). Biomass of livestock and livestock products (e.g. milk, meat, eggs, hides) are not accounted for as biomass domestic extraction, but rather as secondary products.

In addition to used and unsused domestic extraction of biomass (i.e. biomass as a primary product), biomass input flows can also be classified as **imports**, i.e. as traded materials imports of goods into the economy. This classification represents biomass flows as the **trade and processed input flows** into the system, including the products associated with primary and processed biomass (Eurostat, 2009: 78).

On the other hand, when accunting for the *material output side* of an economy-wide MFA, biomass can be distinguished as a throughput. This denotes biomass as a processed output to nature, for instance as a waste flow, a **trade export** or as an **unprocessed output** (disposal of unused domestic extraction).

EWMFA is thus an application of physical accounting to calculate the inflows and outflows of biomasss, and associated indirect flows[3], within the urban metabolism (Hinterberger et al, 2003: 3; Schulz, 2005: 2). As is the case with all material flow accounting mechanisms, EWMFA tools[4] are mainly descriptive and relate to physical inventories and thus, not to elements of environmental assessments (Femia & Moll, 2005: 14). However, as Femia et al (2004: 14) note, material flow tools such as EWMFA can indeed provide the quantiative inventories for further environmental analyses, such as life-cycle assessment. The authors elaborate, stating that without direct knowledge of the pressures, i.e. of the physical flows, further studies on human-

[2] Used domestic extraction denotes raw material extraction directly used in economic processes whereas unused domestic extraction represents those primary material inputs that are not directly used in economic processes (see Eurostat, 2009: 3)

[3] … EWMFA also classifies indirect or "hidden" flows that are either not "visible" in a physical or trade sense (Hinterberger et al, 2003: 4). These indirect flows are associated with imports and exports that represent the 'hidden" lifecyle of primary resource extraction to produce imported or exported goods (Eurostat, 2009: 3).

[4] See Eurostat (2009; 116) for full description of material flow indicators.

induced changes in the environment may find it difficult to proceed (Femia et al, 2005:15).

Accordingly, the Eurostat methodological guide can be used to classify biomass *flows* since MFA is a pure flow concept (Eurostat, 2009: 12). Further, as noted by Eurostat (2001; 26), the main level of classification of domestic extraction can be carried through to all other classification to allow compiliation of sub-accounts and indicators. In terms of these parameters therefore, biomass flows can be classified into the following categories of material inputs:

Table 1 Classification of biomass material inputs (adapted from Eurostat, 2001: 29)

Domestic extraction of biomass		
Biomass		
	A. Biomass from agriculture (primary crops)	
		Cereals
		Roots, tubers
		Sugar crops
		Pulses
		Nuts
		Oil bearing crops
		Vegetables
		Fruits
		Treenuts
		Fibres
		Other crops (spcies, stimulant crops, tobacco, rubber)
	B. Biomass from agriculture as a by-product of harvest	
		Crop residues used as fodder
		Straw used for economic purposes
	C. Biomass from grazing of agricultural animals	
		Grazing on permanent pastures not harvested
		Grazing on other land
	Biomass from forestry	
		Wood including coniferous & non-coniferous
		Raw materials other than wood
	Biomass from fishing	Marine fish catch
		Inland waters (freshwater) fish catch
		Other (aquatic mammals and other)
	Biomass from hunting	
	Biomass from other activities	Honey, gathering of mushrooms, berries, herbs etc.

Although domestic extraction as the main level of classification implies similar classification of biomass imports, there are a few disinctions in the Eurostat (2001: 81-

86) classification of imports. The full, detailed classification[5] of imports is beyond the scope of this paper, but importantly,it includes alive plants as part of biomass agricultural imports and products of biotic kind that can be refined to include horticultural products and other faunal biomass.

The 2009 Eurostat methodological guide notes, however, a number of limitations with its existing classification approach, namely that it has not accounted for:

- *Biomass production from subsistence agriculture and home gardenening;*
- *Biomass waste from management of parks, infrastructure areas, gardens etc.*
- *Biomass harvest from set-aside agricultural land*

A modification of the above classifications to include these three areas. The suggestion is a modified EWMFA classification of biomass that accounts for the flows of plant-based and horticultural biomass, and related processed and traded products, that are not food, feed, animal or wood / timber-related categories (Weisz et al, 2006: 680). This level of detail is necessary to show that despite agriculture often being the largest component of biomass, due to sheer land occupation, there are other production and per capita uses of biomasss that deserve attention, even if they are dominant stastically (Wirsenius, 2003; 47; Weisz et al, 2006: 684). Accounting for these aspects are critical in the light of visions to create a more sustainable city-region and efforts should be made to acquire and collate data on these *where possible*. This is further explained in Secton 7, which notes that the durability of this expanded classification of biomass will depend largely on the accessibility and availability of relevant datasets.[6]

3.2 Ecological footprint analysis (EFA)

The chosen approach for applying EFA in this study focuses on final food consumption. For EFA, food consumption can be classified according to two broad cateogires, (i) food type and (i) whether food is utilised for human and non-human consumption (IWM EB, 2002: 12). An example of this approach is included in *CityLimits* (2002: 12), and shown in Table 2.

The *CityLimits* classification may be valuable as a guideline for sorting and organizing food consumption data. This is because food consumption analysis should include an analysis of beverages, including soft drinks and alcoholic drinks, as well as the packaging inputs into food consumption (IWM EB, 2002: 7; 12; Kerly & Jennie, 2010: 7).

In addition, a robust methodology for assessing food flows needs to incorporate urban food consumption, from different food markets and products, and other key food networks, although these are not the specific classifications addressed in EFA.

[5] Eurostat (2001: 81-86)

[6] Although empirical studies calculating indirect material flows is still quite limited, efforts should be made to account for indirect components of biomass flows (Barles, 2009). These indirect components of biomass flows constitute hidden flows and can be accounted for in "unused domestic extraction" (Salvidar-Sali, 2010:23).

Table 2 Food consumption categories adapted from City Limits (2002: 12)

Food consumption		
	Human consumption	
		Milk & cream
		Cheese
		Meat
		Fish
		Eggs
		Fats
		Sugar and preserves
		Potatoes
		Other vegetables
		Fruit
		Bread
		Other cereals
		Tea
		Coffee
		Miscallaneous
		Soft drinks & beverages
		Alcoholic drinks
		Confectionary
		Starch & starch products
		Production fo ethyl alchocol from fermented materials
	Non-human consumption	Animal feed
		Pet food
	Unidentified	

3.3 System dynamics

Using systems dynamics, biomass can be classified from a stocks perspective where stocks can be expressed in total area or total volume of biomass. However, the specific breakdown of biomass will be based on the specific question or problem to be addressed, i.e. applications of systems dynamics to biomass classification will be driven by the research question. Based on this speciic question or problem, the specific biomass flow and related feedback loops can then be categorised.

Systems dynamics, can however, use the information dervived from EWMFA and EFA. Data emerging from these two classification systems can thus be used to undertake systems dynamics modelling of biomass in the urban metabolism. In terms of the system variables, which define the this metabolism, variables can be cateogorised according to three groupings: (a) variables that are estimated endogenously, (b) variables estimated exogenously and (c) excluded variables.

3.4 Proposed biomass classification

Based on the above classifications, for the purposes of our study, we distinguish between **food** and **non-food biomass.** This can be further broken down into sub-categories of food (including primary products, foodstuffs, beverages and packaging or

processed products for human consumption and that for non-human or animal consumption such as fodder) and non-food (including animal, non-feed and plant-based biomass) (Silvestri & Kershaw, 2010: 24).

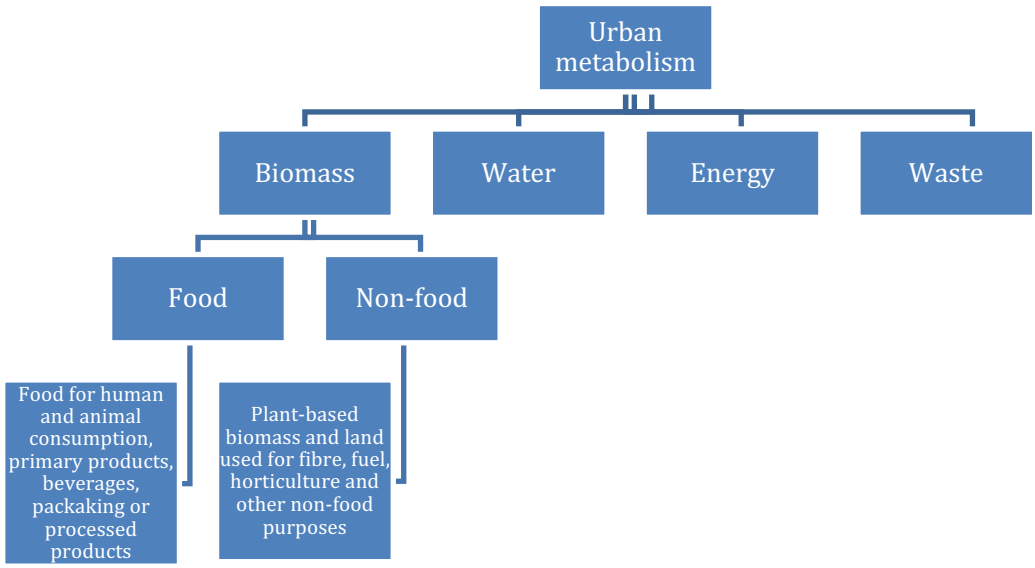

Figure 1 Classification of biomass

4. Physical infrastructure

Mirroring institutional infrastructure, the physical pathways for food flows are complex and multi-tiered. A recent report capturing the diversity of food system infrastructure, states that such infrastructure "covers everything needed for agri-food entrepreneurs to move food from the farm to the plate or to move products, such as compost and timber, from the farm and woodlot to the buyer of those materials" (Michigan Good Food, 2010: 3). As Cellura et al (2011: 194) further note, the complexity of food production often requires a variety of infrastructural processes, operational units and companies, which contribute to the food 'production' chain. We can, however, identify the following physical streams channelling food flows in Gauteng (adapted from Muetzelfeldt, 2010: 7):

- Production systems: including inter alia, various sub-systems such as natural resouces, agricultural inputs, markets;
- Manufacturing, processing and packaging systems: include activites such as storage and machinary;
- Distribution and retailing food: including both physical systems such as transport networks and less tangible infrastructure such as marketing processes
- Consumption systems: including systems of acquiring and preparing food

A food flow assessment for Gauteng needs to provide information on the physical magnitude of food flowing through infrastructure systems, including, inter alia, the magnitude of urban-rural food flows and the relationship between food imports and supplies vis-à-vis consumption and production. However, the nature of Gauteng's food infrastructure also needs to be questioned to answer questions about the efficiecy of systems in terms of water, energy and waste requirements, and the geographical origin of food supply chains. Essentially, data is needed that will provide evidence on what is unsustainable, or sustainable, about the above physical infrastructure systems[7], and how these are of course affected by feedbacks from institutional infrastructure.

The research objective is therefore to collect data that can best represent dynamic linkages between material inputs and outputs on the one hand, and linkages between the food subsystem to the larger urban metabolism, on the other (Decker, 2000: 687).

5. TYPE OF RESOURCE USERS

The food system can be seen as an interactive, interdependent network made up of relationships, decision-making processes and unique use and consumption patterns specific to the individual users in the system. These users (Table 4) all operate within the food value chain (Figure 1), but in dynamic and complex ways to conect producers, procurers, government, industry, wholesalers, distribution firms, retailers, informal and formal users, and ultimately, households to various production and consumption points.

Table 3 Food biomass: resource users and area of use

Food biomass	Users	Area of use
	Industrial • Retailers, • Distributors • Packagers • Hospitality providers (retailers) • Other non-residential users) • Agricultural producers & farmers	Processing
	Households	Consumption
	Government	Policy-making; regulation

6. DRIVERS OF BIOMASS USE AND FLOWS

There are a diverse set of overlapping factors that come together to affect the flow of food in Gauteng. These have been alluded to throughout this paper in different sections, and include (adapted from Muetzelfeldt, 2010):

[7] There are also additional physical infrastructure systems that may affect food flows include auxilary systems, such as sewage networks, through which food waste may inadvertantly flow (instead of through dry waste streams) (Kroll, 2011).

- Mounting resource contraints (e.g water quality and quantity challenges, land change and shortages, deteriorating sol quality etc) as well as climatic changes
- Population and urbanisation dynamics and growing footprint of urban areas, resulting in food supply deficits and further ecosystem pressures
- The regulatory environment e.g. perverse trade subsidies, organic and other labelling / certifications; or Competition Commision Legislation
- The design of physical infrastructure, which affect the way biomass is metabolised in terms of efficiency of access
- Commercial and economic contexts such as affordability of staple foods
- Declining nutritional value of staple foods

There has been a growing body of research on the impacts of the above drivers. The Strategy for a Developmental Green Economy for Gauteng (GCRO, 2010; 43) (Table 4), for instance, show the production-consumption ratio of food in Gauteng, and a study into Johannesburg's Ecological Footprint (PDG, 2011) shows, for instance, consumption drivers for Johannesburg's footprint differ significantly across income categories, with housing being the main driver for wealthiest hosueholds, whereas food is the main driver for poorest hosueholds (PDG, 2011). A number of studies also indicate a prominent interest in a new urban food security agenda particularily around the role of urban and organic agriculture in South African cities (Crush et al, 2011, Rudolph et al, 2011).

Food Group	Current Production		Current Consumption		Nutritional Consumption	
	Total (tons / year)	Area (ha)	Total (tons / year)	Required (ha)	Total (tons)	Required (ha)
Cereals	247,622	72,768	2,757,205	275,720	2,270,222	227,022
Milk	44,323	3,877	395,908	34,630	1,342,039	117,389
Meat	74,711	91,498	347,427	694,855	124,780	186
Vegetables	85,001	3,294	323,424	16,171	1,688,227	84,411
Vegetable Oils	5,579	4,127	35,768	35,768	197,755	197,755
Roots	45,665	1,656	192,912	7,716	0	0
Fruit	8,841	680	292,376	6,497	1,066,915	23,709
Eggs	97,297	116	56,302	9	126,365	21
Pulses	9,250	3,884	123,118	10,260	197,755	16,480
Nuts	140	50	6,912	1,382	185,334	37,067
Other	0	0	661,908	0	20,377	0
TOTAL	**618,430**	**181,951**	**5,193,260**	**1,083,010**	**7,402,729**	**704,040**

Table 4 Comparison of current production, current consumption and nutritional consumption (GCRO, 2010: 44)

From an analytical perspective, therefore, existing research comprising a web of food-related enquiries, need to be analysed and re-interpreted from the lens of infrastructure transitions for more sustainable urban metabolisms. However, data is also needed that reflects in more detail on these drivers i.e. how trends such decreases in potential arable land and school feedings programmes, are affecting production and consumption of food in Gauteng, and how this plays out in relation to household,

specifically. For instance, results from the 2012 General Household Survey show that only 5.9% of households in Gauteng participate in agricultural activities (Table 5), and that learners in Gauteng are also least likely to benefit from school-feeding programmes (GHS, 2012), begging the policy question of whether provincial government is sufficiently thinking through the future of agri-systems.

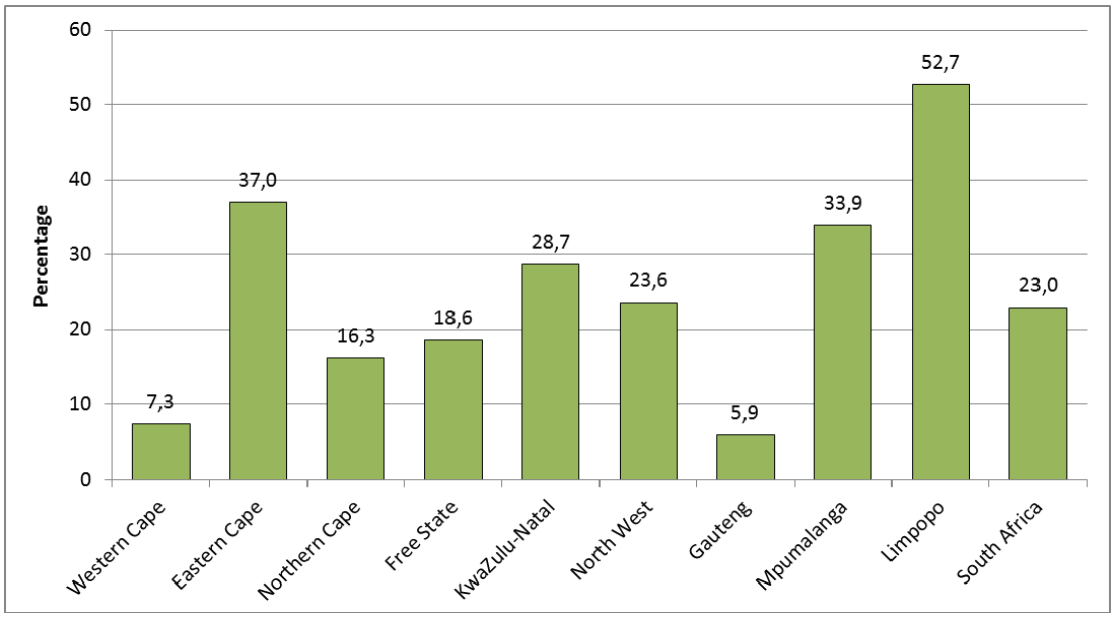

Figure 2 Household involvement in agriculture per province (GHS, 2012)

7. DATA NEEDS AND DATA SOURCES

This sections indicates what data is required for a robust assessment of the biomass metabolism of food flows[8] in the GCR. To achieve this aim, the following section includes a data audit, table 6, outlining the data sources as a preliminary step to developing a harmonised food and non-food biomass database. Although the data sources are presented in a single database, it may be necessary to separate data needs and sources for food and non-food biomass if the need arises. The reasons for presenting a single database is that certain data sources may feed both food and non-food indicators, such as the Census of commercial agriculture (2007) which includes agricultural and horticultural statistics.

[8] Notes:

I. Food can be understood as a transformed input insofar as materials are transformed or converted in the urban metabolism into another (useful) form and then exported from the urban system as waste (Decker, 2000: 687; 689). However, in noting the linkages between different material inputs and outputs, our analysis should also acknowledge that transformed materials ultimately end up being stored as waste (Decker, 2008: 689). A key issue to be addressed is how to the boundary between the food system per se and the waste sector in terms of the flow of for instance, food refuse.

A precurser to be noted is that although data required for the specific methodologies may differ, a number of datasets can serve as simultaneous inputs for these approaches. This implies that although a number of data sources are not designed for an anaylsis of urban biomass flows per se, these datasets can assist in understanding biomass flows and simultaneously serve as data inputs for the three methodological approaches.

Data collection needs are guided by the three methodolgoical approaches utilised in this study, and data needs can be categorised and sorted according to these methodolgoies:

7.1 Economy-wide material flow analysis

The Eurostat (2001; 2009) classification of domestic extraction, including the relevant refinements and modifications, can direct data collection on both physical flows and trade-related data on biomass.

Data for biomass need relate firstly, to local extraction of biomass (such as statistics on primary materials), as an input into the economic system, and secondly, to trade statistics to reflect on the import and export of biomass (Barles, 2000: 905). For the purpose of domestic extraction, data can be sourced from the following (adapted from Eurostat, 2001: 48):

- Agricultural harvest statistics
- Logging statistics
- Fishery statistics and hunting statistics
- Feedstuff statistics
- Estimates derived from land use statistics

In light of trade data requirements, data can be sourced official trade, freight and transport statistics, which give data in both monetary values and physical units (Eurostat, 2001: 49). Importantly, international studies have shown that trade data on biomass imports and exports provide a suite of indicators of potential indicators and the impacts of heavy dependence on external ecosystems (Weighell, in UK NEA, 2011: 1049).

To account for indirect flows, we can investigate data to serve the purposes of other methodologies, such as input-outout analyses, substance-flow analysis and life-cycle assessment[9].

7.2 Ecological Footprint Analysis (EFA)

EFA will be used to cast light on food consumption types and the resource users or consumers of food types. For such purposes, data wis required on consumption of food

[9] JM can you advise on how this works in relation to biomass

by both humans and non-humans. This is because the primary question for EFA is to uncover *who* is consuming *w*hat. This implies data collected on resource users and their respectives area of biomass use. Information on these items can be gathered from the regular monitoring and reporting of agricultural indicators in government, industry and markets; official consumption and expenditure stastistics and dervied from existing pilot studies on food consumption. Drawing on a neighbourhood study conducted by Codoban & Kennedy (2008: 23), it would be valuable if data is collected on the amounts of food entering households, both consumed and wasted.

Additionally, data is also required on specific indicators included within EFA such a s biocapacity, equivalent facotrs, yield factors[10].

7.3 System dynamics

While static representations of food and non-food biomass can be dervived from the prior two methodologies, system dynamics can direct data on future trends and dynamics for a specific system. Specifically, system dynamics can be used to collect data on stocks and variables within a biomass metabolism and initally, it can be used to represent the factors affecting this metabolism described in precedinf sections. Broader variables such as changing institutional arrangements, urbanisation and popualtion dynamics and dynamics relating to ecological, economic and other subsystems will be the major focus of such data collection efforts.

Importantly, while data collection for this method can be derived from EWMFA and EFA, there are a number of data sources that provide information on the drivers of biomass flows. These include StatsSA publications and datasets from data services providers such as GT, Quantec and ESRI.

7.4 Issues relating to data colelction

7.4.1 Disaggregation

Primary data on biomass at the relevant provincial and regional scales may prove to be a challenge for our data collection efforts. Data at provincial, metropolitan and municipal level for biomass as defined in ths paper is scarce. Although national statistics may permit the monitoring of biomass inputs into the economy, in terms of the relationship between domestic production, imports, exports and net consumption nationally, this may not be the case for a regional or local analysis for the GCR itself (Weighell, 2011: 4), In light of this, we acknowledge that a significant degree of re-interpretation and re-organisation of existing aggreated data may be required.

7.4.2 Accessibility to information

One primary challenge is the willingness of data sources to share information. The following statement by the National Chamber of Milling reflect this challenge:

[10] See detailed explanation of these indicators in (Wackarnagel, 2004)

> *"Following the Competition Commission concerns regarding information sharing, the Chamber has discontinued with the dissemination and distribution of industry statistics until such time when the Commission has given clear guidelines regarding information sharing on an industry basis" (NCM, 2011).*

A further challenge to be addressed is the relationshup between trade flows and primary production figures. For instance, companies registered in Gauteng that use biomass, through exporting tomatoes for instance, may register trade through the Province, but the source of this is produced elsewhere.

To address such challenges, it will be crucial to engage with indsutry assocaitions such as South African National Seed Oorganisation (SANSOR), which representes 98% of seed players in South Africa, of which many stakeholders are based in Gauteng. SANSOR can guide data collection efforts on inter alia, cereals, grain crops, pastures, vegetables. This data is for total volume of seed sold on various crops, produced and exported, although efforts will be needed to organise this data at a Gauteng scale.

8. CONCLUSIONS AND RECOMMENDATIONS

This study recommends that the three guidelines methods are seen as complimentary approaches to directing data collection. The recommendation is that a roboust biomass flow assessment requires specific foci, particularily given the time, financial and resource constraints of this research project. The recommendation is to concentrate data collection efforts around food flows data. Four broad focus areas are suggested in this regard:

Trade and Market analysis of the Gauteng Food and Agricultural Sector
Data collection in this regard will relate to the Gauteng Province's food flows as part of EWMFA. Consultation of official statistics such as StatsSA in conjunction with other market-related statistics will be useful in understanding the composition of the formal agrifood sector. This is suggested as a way to address possible challenges in accessing data from large supermarket chains and retailers unwilling to provide detailed information on their market shares. It is recommended that this data collection exercise is undertaken by the GCRO internally, in conjunction with the expertise of research agencies with historical advantages in food research.

Analysis of household food consumption
The study recommends a focus on household food consumption to understand 'final consumption' dynamics in food systems, which may be underrepresented by exclusive focuses on foods traded. This contribution to EFA is important for a number of reasons highlighted in this paper, including increasing reliance on the informal or 'street' food sector, indicators of dietary diversity and socioeconomic and spatial differences in where people source food from and what food people eat. The recommendation is to utilize existing research on household food consumption, such as that conducted by

research agencies such as Siyakhana Initiative for Ecological Health and Food Security, and build on this where necessary.

Agencies such as Siyakhana have conducted detailed stakeholder analyses of food consumption in households that need not be replicated. While these analyses are case-specific, they provide useful benchmarks to estimate the food footprint of certain households and income groups, and the survey methodologies useful to do so. It is suggested that the GCRO identifies the extent to which such available data can be accessed, if useful, and where such data collected is to be utilised in this regard.

Modelling spatial distribution of, and access to, food flows

The GCRO has a robust set of skills in the broad area of Geograpgic Information Systems (GIS) and has collected a substantial amount of spatial data in the areas of agricultural production, population dynamics, land use change and economic geographies, which from an analytical perspective, come together to characterise the socio-spatial economy of food flows. The spatial data collected thus far can be utilised, re-interpreted and further interrogated to provide information on the socio-spatial nature of food flows. Such a spatial analysis is recommended given the distinct political geographies that characterise food flows and patterns of production, distribution and consumption. To this end, it is suggested that the GCRO utilise existing spatial data collected thus far on agriculture, land use and other relevant variables, to spatially represent food flows. The GCRO's GIS interns and student assistants can assist in these tasks.

Trade analysis of food flows in Gauteng's fresh produce markets

The recommendation is to focus on the four fresh produce markets in Gauteng, namely the Johannesburg Fresh Produce Market, the Pretoria Fresh Produce Market, the Vereeninging Fresh Produce Market and the Springs Fresh Produce Market. The essence of this study will be to collect data on the physical flows of food and foodstuffs, as a component of EWFA, through the markets, as major points in the food supply chain in terms of where food sold at the market is sourced from, quantities traded and where this trade ends up in the wider value chain.

Data collection for this focus area is likely to veer towards trade flows, a major component of the GCRO's project, 'Transitions to a future economy: trade and the GCR", which examines trade flows into and out of the GCR and establish their potential contribution and costs to the GCR economy. Since this project will involve fieldwork with traders in Gauteng's fresh produce markets, the suggestion is to begin a process of inter-project data collection to minimise data duplication and the costs of field work for each project.

Since fresh produce markets record daily trade activity, it may be possible to track detailed data of food flows in each market, including the flux of different foods traded of food flows. It is further suggested that GCRO may wish to explore possible avenues of engaging with the University of the Witwatersrand and the University of Johannesburg in the collection of data to collaborate with our partner institutions. This may include the involvement of a Masters or Honours Level students in the collection of data or students already included in food-related research agencies at either institution.

In light of the above, we suggest that the following proposed areas of investigation during Phase I:

Proposed investigation	Responsible person
Trend and Market analysis of the Gauteng Food and Agricultural Sector	External research agency, managed by JKM
Household food consumption analysis – case study(ies)	External research agency, managed by JKM
Modelling the spatial distribution of food flows	GCRO Interns, Masters student, managed by JKM
Trade analysis of food flows in Gauteng's fresh produce markets	Masters student – collaboration with (Wits/ UJ); School of Public Health

A general recommendation

The Siyakhana Initiative for Ecological Health and Food Security has a longstanding involvement in the food security sphere. This includes involvement with the South African Food Lab; the policy and programme analysis work recently conducted through the GCRO; a strong network capital with the private sector, local and provincial government, various community support organisations and the fresh produce markets operating in Gauteng.

In addition to an important institutional role, the Siyakhana Initiative includes a core team that holds competency in the areas of food-related research design, administration and management, as well as strong interpersonal communication skills which are useful for interviewing and training interviewers and data capturers. This core team is supported by a junior researchers who have established valuable data-collection and communication skills through their involvement in two previous food-security-related research projects, and have strong language competencies spanning approximately 9 languages relevant to Gauteng's geographical area.

The recommendation is for the GCRO to engage with the Siyakhana Initiative in the process of data collection to capitlize on Siyakhana's strong links in the sector and faciliate the ease of data collection. Siyakhana is also part of the School of Public Health at the University of the Witwatersrand and can assit GCRO in its collaboration with tertiary education bodies.

In addition, however, GCRO can also enagege with a number of select research institutions, such as Global Change and Sustainability Research Institute (GCSRI) under the theme "Urban Resilience Assessment for Sustainable Urban Development (Prof Phil Harrison), and other research arms of Wits and UJ, with specific interests related to the study. The suggestion is to bring on board post-graduate students and researchers, either at PhD and Masters-level, to assist with primary data collection and methodological issues, relating to how we rethink the sustainability of the GCR in terms of biomass. Such a collaboration will be supported by the GCRO in its support for field research, data collection and other research-related activites. The aim is to combine a set of post-graduate projects into a comparative framework to identify the problems that require dynamic systems modelling, and in cases where such problems have been identified, to provide the primary data to assess the sustainability of our biomass appropriation. This will be part of setting up a wider knowledge network or

what has been termed a 'community of practice' on how to faciliate urban metabolism studies.

In summary, data collected during Phase I of this multi-year project needs to help us understand a number of complex, interrelated dimensions of the biomass metabolism in relation to food flows. These are:

A. Estimates of the physcial magnitude of food biomass flows
B. The physical and institutional configuration of infrastructure networks channelling and delivering food flows
C. The interface between political economic factors and configuration of regional food infrastructure
D. The affect of agri-food systems on peoples' access to food and the distribution of food flows
E. The interaction between food flows and other components of the urban metabolism

To execute the above, we recommend a four- to six- month data collection process that uses the data sources in Table 6 as a guide. While data collection will be primarily focused on food flows, where datasets are cross-functional and can yield insights into non-food flows, this must be capitalised upon. To kick-start Year 2 of phase I of this research exercise, the suggestion is for a closed tendering process during which research organisations and indivuals can bid to undertake the data collection process. The budgetary parameters of this tender are set in the 2012/2013 GCRO Budget for Metabolic Flows, and R200 000 is planned for this task.

In addition, the chosen bidder will be required to interact closely with the GCRO project team that compiled this study and maintain a close working relationship with the project manager and the project team in synthesising the data.

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Annexure

Methodological parameters

The study applies the methodological parameters defined within "Towards assessing the metabolism of the Gauteng City-Region" (GCRO, 2011) to an analysis of the GCR's biomass metabolic profile. The study acknowledges, however, that there exist limitations with the respective methodological approaches and where such constraints exist, we aim to capture the categories of urban biotic networks to better interrogate the socio-natural urban form and its flows and functions (Rapoport, 2011: 20; Broto et al, 2011: 11).

The project is guided by the following methodological approaches:

a) Material Flow Analysis (MFA) with a specific focus on Economy-Wide Material Flow Analysis (EWMFA). EWMFA accounts for material exchange between national or regional economies and (a) the domestic environment (via resource extraction on the input side and waste deposition, and releases to air and water, dissiapative uses and loss (on the output side), and (b) other economies (via trade) through measuring material flows in physical units (Schepelmann, n.d: 2).

   For the purposes of EWMFA, this paper applies the principles and materials grouping developed by the Statistical Office of the European Communities (Eurostat 2001). As noted by Barles (2009: 899), the Eurostat method has been used extensively and importantly, it allows "comparisons between studies on different territorial scales – national *versus* regional or urban – and between cities and regions". The Eurostat guidelines have been applied in a variety of contexts to provide a basis for comparative analysis and benchmarking exercsises. To this end, the Eurostat MFA methodolgocial guide introduces a number of resource use indicators that can be utilised in benchmarking this findings contained within this study against other urban regions that have conducted simialr work.

   As such, this study follows the Eurostat conceptual framework to classify physical biomass flows in the GCR using material inputs and material outputs economy-wide MFA. This classfication, which is further explained in section 3, will be used as a basis to provide aggregate overviews of annual material inputs and outputs of an economy, including imports and exports, specifically related to biomass (Saldivar-Sali, 2010; 22).

   We acknolwedge, however, the limitations of an EWMFA and attempt to address them where possible. First, compared to water, energy and waste flows,

which are frequently studied in MFA, there exist few comprehensive studies of global biomass flows, on which there is much less evidence and methodological robustness (Krausmann et al, 2008: 472; Minx et al, 2010: 79). Furthermore, where data has been collected on biomass flows, it is often in national format so that disaggregared data at an urban and regional scale is a challenge to be addressed in this study (Barles, 2009).

On the other hand, EWMFA may be viewed as a simplistic view of a biomass due to the inherently linear nature of input and output analyses (Rapoport, 2011). As Barles (2009: 911) states, it is important that future MFAs link to the "particular socioecological conditions that influence material flows and their evolution". Notwithstanding this limitation, the study takes the view that we should first endeavor to apply tested methodologies, such as Eurostat, as a guideline to data collection, and then seek to expand and merge this with other suitable urban metabolism approaches. It is also noted that EWMFA is a physical accounting approach and is useful for the purposes of material flow analyses, whilst other research questions, such as the stock of biomass accumulated in Gauteng, may be better answered by using additional methods.

One of the major unanswered issues is the capability of an EWMFA to capture the hidden flows that characterise the urban environmental imprint (Barles, 2009: 911). This report presents evidence that capturing passive flows may be better achieved through case-specific analyses, such as life cycle assessments or substance flow assessments, rather than EWMFA. On its own, EWMFA may not suffice to address the flow of indirect flows such as ecosystem services. Question such as how changes in natural systems functions lead to changes in the flows and the value of ecosystem services may be better addressed through methods such as agent-based modelling or ecosystem service valuations (Silvestri & Kerhsaw, 2010: 27). Importantly, the integration of EWMFA and other methodologies is a key issue to be addressed for future urban metablism research and we make recommendations on these conceptual interlinkages.

b) Ecological Footprint Analysis (EFA) is an accounting framework measuring human appropriation of ecosystem products and services in terms of the amount of bioproductive land and sea area needed to supply such products and services (Ewing et al, 2010: 1).

   EFA aims to calculate final consumption for a population in the economy, including waste flows such as CO_2, and the amount of land that is necessary to sustain that population indefinitely (GCRO, 2011: 23)[11]. In terms of biomass, this study's application of EFA will analyse final food consumption and the total area required for consumption of food in the economy. Data on final consumption will be used to estimate land requried to support food consumption, and related waste emissions, from this consumption.

[11] See Methodological Document for full explanation a methodological procedure for ecological footprint (GCRO, 2011: 23-27).

The task for this study is to identify data for different types of food consumption for Gauteng, according to the classification of food consumption described in section 3. In terms of EFA, a number of indicators will be utilised to calculate final consumption of food. These include, inter alia, local yields, food production resources, land use in terms of hectares and indicators of biomass productivity versus bioproductive capacity.

c) System Dynamics is an interdisciplinary method for understand the dynamic behaviour of complex systems, and how these system change over time (GCRO, 2011: 27). The system parameters used by system dynamics include stocks, flows, flow-variables, which are used by systems dynamics to descirbe a given system and through which biomass flows in Gauteng will be represented[12].

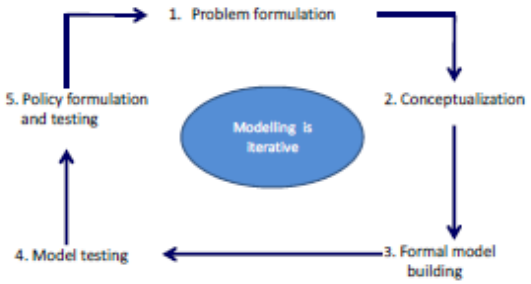

Figure 3 System Dynamics Modelling Process

This study will follow the general system dynamics modelling process as described in the GCRO's 2011 methodology study (Figure 1). However, One of the major distinctions between system dynamics modelling and the previous two methodological parameters the role of problem forumlation (GCRO, 2011: 29). An analysis of biomass flows using system dynamics therefore requires detailed formulation and conceptualisation of a biomass-related problem or question within the system, such as the negative effect of climate change on agricultural stocks in Gauteng. It is crucial that time delays and feedbacks related to the specific biomass problem are included in the modelling process.

Methodologically, we can also use systems dynamics to represent the interlinkages between resources, as described by Abou-Abdo et al (2011): "Using System Dynamics modeling techniques, we link the stocks and flows of seven classes of resources—water, energy, construction materials, industrial minerals, biomass, petrochemicals, and finished products— with drivers and behaviors in the urban system". We can therefore use system dynamics to represent and simulate biomass stocks on the one hand, and the relationships between changes in biomass and additional flows, and other variables, such as hydrology and biodiversity.

To conduct a dynamic analysis, Abdoue-Abdo et al (2011) note that an initial step is the development of a dynamic hypothesis that could explain the relationships between resource stocks and flows and urban dynamics at multiple scales, which in-turn the description of a system model. A dynamic hypothesis are in-turn requries the creation of casual loop diagrams, designed to identify and explain relationships in the specific problem.

[12] See Methodological Document for full explanation a methodological procedure for ecological footprint (GCRO, 2011: 27-31).

Table 1 Institutional arrangements affecting biomass (adapted from Green Strategic Programme for Gauteng, 2011)

National	
Policy document/strategies/ legislation/ plans	**Purpose**
Integrated Food Security Strategy of South Africa (IFSSSA) (2002)	The goal of the IFSSSA is to eradicate hunger, malnutrition and food insecurity by 2015. The aims are increase household food production and trading; improve income generation and job creation opportunities; improve nutrition and food safety; increase safety nets and food emergency management systems; improve analysis and information management system; provide capacity building; and hold stakeholder dialogue.
National Integrated Food Security Policy	In draft format but aims to shift procurment to emergin and msall-scale farmers, establish localf ood economies and increase nutrition and education efforts.
Zero Hunger Strategy	Support small-scale agriculture, procurement of local foods, establish community nutrition centres, skills development
Competition Commisions / Law	Monitoring of information exhange in South African industires to control anti-competitive behavious
Conservation of Agricultural Resources Act (Act No. 43 of1983)	Control over the utilisation of natural gricultural resources; only active legislation on weeds and invase plants and determines purposes of Working for Water Programme; despite a national Act, the responsibility lies with Province.
Fencing Act, 1963 (Act No. 31 of 1963)	Regulates matters of boundary fences fo farms and obligatory contribtuion to boundary fences; responsibilities lie with Province
Animal Diseases Ac, 1984 (Act No. 35 of 1984)	Control meausres for the prevention of diseases and parasites; nationalact but provncial mandate to implement
Abattoir Hygiene Act, 1992 (Act No. 121 of 1992)	Maintenane of propoer standards of hydience in the slaughtering of anmials and handling of meat and animal prodcuts; national act but provincial mandate
Control of Markets in Rural Areas Ordinancen, 1964 (Ord. No. 38 of 1965)	Directoriate of Agriculture and Rural Development
Problem Animals Control Ordinance, 1978 (Ord. No. 14. Of 19780	Directoriate of Agriculture and Rural Development
Fertilizers, Farm Feeds, Agricultural Remedies and Stcok Remedies Act, 1946 (Act No. 35 of 1947)	Registration of fertizliers, stock feeds, agricultural remedies, stock remedies, sterilising plants and pest contol operators.
Livestock Brands Act, 1962 (Act. No. 87 of 1962)	Regulates registration of a brand in the name of an owner of livestock to dientify livestock.
Agrciultural Credit Act, 1966 (Act. No. 28 of 1966)	Provides for assitance to persons carrying on or underaking to carry on farming operations
Marketing Act, 1968 (Act. No 59 of 1969)	Introduces systems of control over the marketing of agriclutral products and regulates quantitative control over the import and export of tehse products
Wine and Spirit Control ACT, 1970 (Act No. 47 of 19700	Regulates the control and management of the wien and spirit industry by KWV.
Subdivision of agricultural land act, 1970 (Act. No. 70 of 19070)	Regulates subdivison of agricultural alnd and its sue for purposes other than agriculture.
Plan Breeders' Right Act, 1976 (Act No. 15 of 1976)	Regulates granting of certain rights relating to new varities of certain kinds of plants, the protection of such rights and the isseu fo licenses in respect of exercising rights.
Plant improvement Act, 1976 (Act No. 53 of 1976)	Regulates registration of establishments where plants an dpropogation material are sold and packed, for the introduction of schemes for ceritifcation.
Livestock improvement Act, 1977 (Act. No. 25 of 1977)	Regulates collection and sale of semen and ova and the artificial insemination and inovulation of certain animals, the establishment of a system for the evaluation and certification of the performance of certain animals, quality control with regard to the importation and exportation of certain animals, semen, ova and eggs, the incorporation of livestock breeders' societies and the maintenance of the legal personality of livestock breeders' societies, and the granting of certain exclusive powers relating to the registration of pedigrees of certain livestock to the South African Stud Book and Livestock Improvement Association.
Desingated Areas Development Act, 1979 (Act. No 87 of 1979)	Provides for measures for the promotion of the density of population and of farming activity in certaina areas.

Co-operatives Act, 1981 (Act. No. 91 of 1981)	Regulates the formation, registration, management and functioning of various types of cooperatives
Veterinary and Para-veterinary Professions Act, 1982 (Act No. 19 of 1982)	Provides for the establishment, powers and functions of the SA Veterinary Council
Perishable Products Export Control Act, 1983 (Act. No.9 of 1983)	Provides for the control of perishable products intended for export and the continued existence of a stautory board
Agricultural Pests Act, 1983 (Act No. 36 of 1983)	Prevention and combatting of agricultural pests.
Liquor Products Act, 1989 (Act No. 60 of 1989)	Control over the sale and production for sale of certain liquor products, the composition and properties of such products etc.
Agricultural Research Act, 1990 (ACT. No. 86 of 1990)	Juristic person to undertake agricultural research and regualtes matters regarding the ARC.
Agricultural Products Standards Act, 1990 (Act. No 119 of 1990)	Control of sale and export of certain agricultural products and other related products
Agricultural Produce Agents Act, 1992 (Act No. 12 of 1992)	Establishment of Agricultural Produce Agents Council
South African Abattoir Corporation Act, 1992 (Act No. 120 of 1992).	Privatization of the South African Corporation.
Agricultural Development Fund Act, 1993 (Act No. 175 of 1993)	Control over an agricultural development fund.
Provincial	
Policy document/strategies/ legislation/ plans	**Purpose**
Strategy for a Developmental Green Economy for Gauteng (2010)	Identifies local food productin as a strategy to promote a green economy
Gauteng Employment Growth and Development Strategy (GEGDS) (2010)	Identifies food secuirty as a key motivation for green grwoth and development
Gauteng Social Development Strategy (GSDS) (2006)	Through strategic levels, improve foods secuirty as a step tp reduce poverty and hunger
Gauteng Comprehensive Rural Development Strategy (GRDS) (2010)	Development of rural communities through developing food security through several measuressuch as backyard gardens, community food gardens and food banks.
Gauteng Agriculture Research and Development Policy (GARDP) (2008)	The purpose of the policy is to outline principles and parameters of agricultural research for the development of appropriate agricultural technology and increasing agricultural productivity within the province of Gauteng.
Gauteng Agricultural Development Strategy (GADS) (2006)	Aims to support the GEGDS through developing agriculture.
Gauteng Biotechnology Strategy (2007)	This strategy responds to GADS and the GEDS to create a strategic framework with the intention of positioning Gauteng as a national leader in biotechnology,
Gauteng Integrated Food Security Strategy and Policy (GIFSSF)	This is a policy document guiding the implementation of the GIFFSF with refined roles of different departments. The document has a strong focus on the co-ordination between provincial departments and outlines the food-for-all rollout plan.
Local	
Municipal Integrated Development Plans (IDPs)	Most municipalities have a basic set of food security related programmes in common that relies heavily on the local production of food in homestead and community gardens. Improving the availability of land and providing inputs and implements are put forward as strategies to increase production
Food secuirty proogrammes	
War on Poverty & Bane Pele (cross-departmental)	Established to assist poorest households through food banks and school nutrition programme while bane pele includes services such as school feeding
Community Work Programme (CWP)	Direct employment creation programme
National School Nutrition Programme	Providing regular nutrition for youg learners
National Radio Active Waste Act 53 of 2008	To provide for the establishment of a National Radioactive Waste Disposal Institute in order to manage radioactive waste disposal on a national basis; to provide for its functions and for the manner in which it is to be managed;

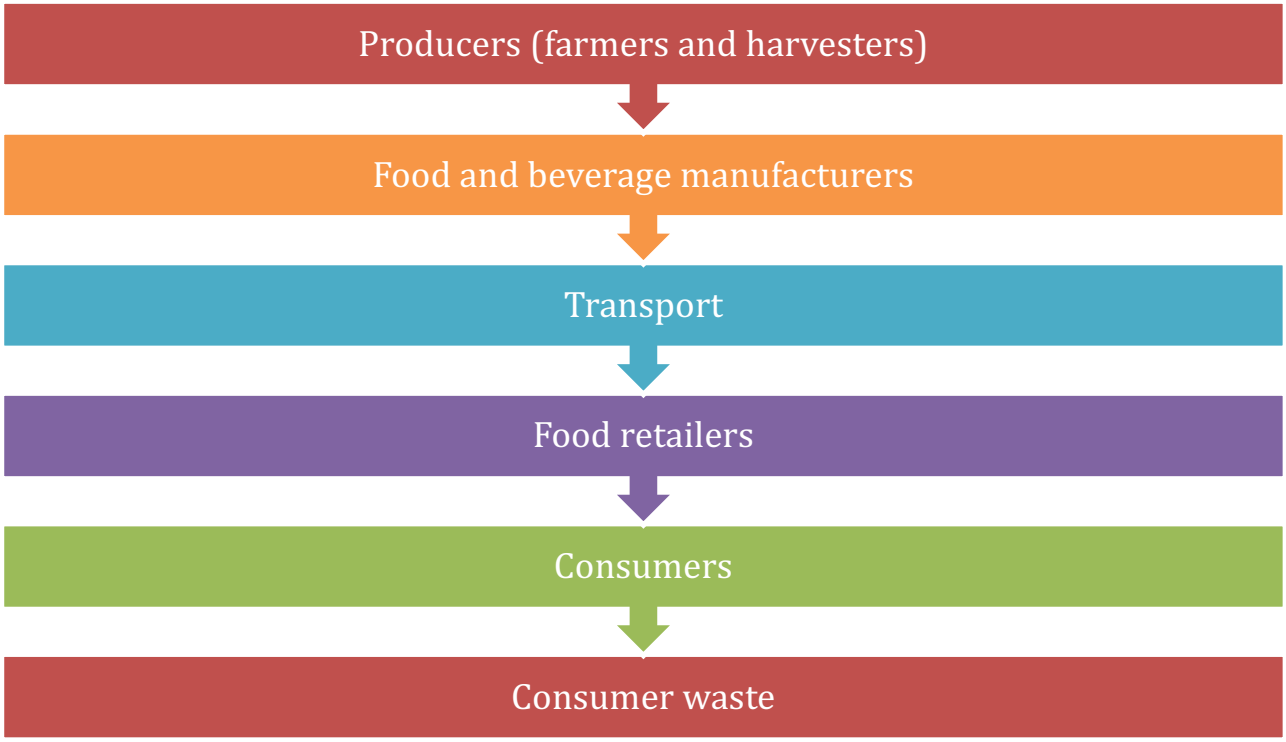

Figure 4 A typical food value chain

Table 5 Biomass data sources

Government data	Flow	Data source	Type of data	Units	Link	Remarks
	Primary extraction	StatsSA Census of commercial agriculture, 2007 Gauteng	Provincial statistics for selected products: field crops, horticulture, animals, animal products		http://www.statssa.gov.za/publications/Report-11-02-08/Report-11-02-082007.pdf	
	Primary extraction	StatsSA Census of Commercial Agriculture	Interactive time series database: area planted production information	Hectares (area planted) and metric tonnes (production)	http://www.statssa.gov.za/timeseriesdata/pxweb2006/Dialog/statfile1.asp	
	Final consumption	StatsSA Income and Expenditure Survey	Expenditure data	Rand value	http://www.hsrc.ac.za/Document-3579.phtml	
	Trade flows	DAFF	Soybean market value chain profile: Soybean Gross value; production in tonnes		http://www.daff.gov.za/docs/AMCP/SoyabeanMVCP2010-2011.pdf	
	Primary extraction	DAFF: Crop estimates committee	Crop estimates	Area planted (Hectares) finacl crop production (tonnes)	http://www.sansor.org/pdf/marketdata/crop_estimates_committee_2011_7.pdf	
	Trade flows	DAFF: 2010	A profile of the South African Tomato Market Value Chain	Rand Value	http://www.daff.gov.za/docs/AMCP/TomatoMVCP2010-11.pdf	
		DAFF Quarterly Economic Overview of the Agriculture,	Provincial agricultural employment			

		Forestry & Fisheries Sector				
		GDARD Gauteng Agricultural Census	Spatial aerial surveys and data of crop and livestock production within Gauteng	Geo-spatial imagery of farm infrastructure, field boundaries and crop types for summer and winter, herbs, flowers, livestock, orchards, vegetables, tunnel information; all **shapefiles with attributes**	http://www.siq.co.za/index.php?option=com_content&task=view&id=53&Itemid=123	Received GDARD CD; Celiwe Kgowedi 084 5122 609; celiwe.kgowedi@gauteng.gov.za
	Trade flows	DAFF Market value chain profile & "Crops & Markets" document for 4 financial quarters	Agri marketing data; volumes of fresh produce traded	Volumes Mass in tonnes, value and average price	http://www.daff.gov.za/docs/statsinfo/Crops_0304.pdf	Percentage distribution of area planted v.s production for different crops across South Africa This is an important government analysis
	Trade flows	DTI	Agro processing & export data	Rand value	http://apps.thedti.gov.za/econdb/raportt/rapsiAGROPROCEScurrent.html	National aggregated data.
	Trade flows	South African Revenue Services (SARS)	Imports and exports of foodstuffs			
		Jhb City Parks				
Industry association data	**Drivers of biomass flows**	Elsenberg 2005	A profile of demographics, poverty, inequality and unemployment: statistics for agricultural and non-agricultural holdings		http://www.elsenburg.com/provide/documents/BP2005_1_7%20Demographics%20GT.pdf	

		JSE SAFEX Commodity Derivatives	Agricultural commodity prices; agricultural daily statistics		http://www.jse.co.za/Markets/Commodity-Derivatives-Market.aspx	
	Resource users	Seedling growers association of South Africa	Nursery data; GPS coordinates		http://www.seedlinggrowers.co.za/	Very limited Gauteng data; no specific / extensive data
	Seed as a primary biomass input	South African National Seed Organisation (SANSOR)	Total volume of seed sold in various crops; total seed sales in SA; Seed statistics for cereals, grain crops, pastures, data on volume of seed	Kilograms and Rand value per crop and seed	http://www.sansor.org/	National data but very useful contact Gerrie Reitsma 012 349 0066; gerrie@sandsor.co.za; SANSOR represents 98% of seed industry; SANSOR reports subject to independent audit
	Primary extraction and trade flows	Animal Feed Manufactures Association (AFMA)	Animal feed sales statistics		http://www.afma.co.za/	
	Trade flows	National Agricultural Marketing Council (DAFF)	Manage crop estimates; Food trade flows, fruit,		http://www.namc.co.za/dnn/default.aspx	Seasons perspective: go direct to companies to data - based on seed sales vs. market share; each month varies
	Primary extraction	Agricultural Research Council (ARC)	Production and consumption		http://www.arc.agric.za/home.asp?pid=33&sec=741	
		Agri World SA	Directories for various products		http://www.agriworldsa.com/about-us	Advertising, communication and information portal.
		SA Agricultural Processors Association			http://www.grainmilling.org.za/	Falls under auspices of National Chamber of Milling.
		South African Meat Industry Company / SA Red Meat Industry Forum			http://www.samic.co.za/ http://www.agriworldsa.com/nurseries-1/samic	

	Resource users	National Chamber of Milling	Database of industry suppliers		http://www.grainmilling.org.za/	Boikanyo@grainmilling.ord.za; 012 663 1660 Jannie de Villers May be able to give data on provincial consumption of e..g malt
	Trade flows	SA Fresh Produce Exporters' Forum			http://fpef.co.za/	
		SA Fruit & Vegetable Canners Association & SA Fruit and Vegetable Canners' Export Council			http://www.safvca.co.za/	
	Non-	SA Feedlot Association	Market indicators: kgs, average cost / price, mass		http://www.safeedlot.co.za/	Aggregated data
		Bureau for Food and Agricultural Policy	Potential arable land, cultivated land, exports, processing	hectares	http://www.bfap.co.za/	
		CSIR Bio	Imports of cooking coal, production and consumption of blast furnace gas from iron and steel			Detailed data not available online, interaction with CSIR required.
		SA Grains and Oilseeds			http://www.sagrains-oilseeds.co.za./ http://www.sagrains-oilseeds.co.za./	
		Agrimark	Provides market information, research and advise to the agricultural sector; including monthly reports for certain crops; temporal data	Tonnes and price	http://www.agrimark.co.za/	Has data for fresh produce markets e.g price and volume sold of e.g. carrots on the Jhb Fresh Produce Market

	Trade flows Primary Extraction	South African Grain Information Service (SAGIS)	Imports, exports, prices, historic databases, time-series data, deliveries, stock-tables, provincial breakdown, time-series; **area planted provincially for different grain crops**		http://www.sagis.org.za/	SAGIC has good quality information (which implicitly means they have the raw quantity data somewhere) Nico Hawkins to take over as CEO Weekly imports and exports of different crops although this seems largely aggregated; seasonal production forecasts – good resource.
		Winter Cereal Trust	Wheat, oats etc.			Avie Coetzee 012 663 1660; 082 379 1451
		Mintek?				
			Industry data, trade flows			
		SA Medical Research Council	?		http://www.mrc.ac.za	
		DST-NRF Centre of Excellence for Invasion Biology	Invasive species (?)		http://academic.sun.ac.za/cib/	
					http://www.hsrc.ac.za/	
		AFMA (Animal Feed Manufactures Association)	Animal feed sales statistics (national)		http://www.afma.co.za/ http://www.afma.co.za/imgs/April%202011%20until%20July%202011%20-%20Global%20Feeds%20Sales%20and%20Raw%20Materials.pdf	Aggregated national data: volumes of feed consumed but AFMA is likely to have the raw data for volumes for Gauteng and importantly, access to main players such as Meadow, AFRGI Feed, Roussouw
		Forest and Forest Products Research Centre (CSIR)	Remote sensing and modelling of forest ecology, forest mensuration, estate management, resource management		http://ffp.csir.co.za/	Detailed data unavailable online

		AgriSA	Links to other important organisation		http://www.agrisa.co.za/Index.html	
		SA Cotton Producer's Organisation				To be investigated
		Grain SA	Market info		http://www.grainsa.co.za/index2.php?	Use microlites that use aerial photographs
		SA Poultry	Poultry statistics		http://www.sapoultry.co.za/	Kevin Lavelle
		Association of meet importers and exporters (AMIE)			http://www.amiesa.co.za/	
	Trade flows	Red Meat Producers' Organisation	Imports and exports	Monthly volumes in kgs for red meat	http://www.rpo.co.za/	Appears to be a good data source but data mining would be necessary for a Gauteng study Gauteng contact: saaijman@saaijmangrey.co.za
		Potatoes and Onions Committee			http://www.korkom.co.za/	"Sole purpose is to gather information on potaotes"
		SA Fruit Farms	Contacts and various directories		http://www.safruitfarms.com/exporters.aspx	Has a directory of fruit exporters, grower groups, gorwing areas
		The RSA Group			http://www.rsa.co.za/?q=node/3	
	Trade flows	Jhb Fresh Produce Market	Volumes and daily prices	Rand value and Kg	http://www.joburgmarket.co.za/ http://www.joburgmarket.co.za/contactus.php http://www.safruitfarms.com/Default.aspx?tabid=457	See DAFF report on market trends But useful information on total value sold, total quantity sold and total KG sold Important to check Jhb market agents This is a corporatized market

		Pretoria fresh Produce Market	Historical data of volumes and daily prices, sales value	Mass, tonnes, Rand Value	http://www.safruitfarms.com/Default.aspx?tabid=308 http://www.tshwane.gov.za/Services/Tshwane%20Market/Pages/default.aspx	Important to check Pretoria market agents This is a City of Tswhane
		Vereeniging Market			http://www.safruitfarms.com/Default.aspx?tabid=318	This a Sedibeng District Council Market
		Springs Fresh Fresh Produce Market			http://www.safruitfarms.com/Default.aspx?tabid=311	
	Trade flows (production?)	Flower Market				
		OPOT	Sunflower, soy & canola			Gerhard Keun & Gerhard Scholemeyer
		Dry Bean Organisations & Marketing Organisation			www.beans.co.za	Chris Kleingeld chris@beans.co.za; 082 288 0500; important part of proteins
	Trade flows	SA pork	Import figures; orice ratios; total numbers slaughtered per province!	tonnes	http://www.sapork.com/	Largely national data but there are provincial organisations (Limpopo; North Free State; Wed-Transvaal; Gauteng); and slaughter numbers per province 012 361 3920 info@sapork.com Gauteng Pig Study Group: Dries du Plessis; 012 460 9285
		Premier Pork Producers			http://www.premierpork.co.za/index.php?option=com_content&task=view&id=13&Itemid=26	Represents 60% of the country's pork and likely to have data from the industry
		Pig Breeders' Societ of South Africa	Database of registered pig abattoirs, breeders and breeding companies		http://www.studbook.co.za/Pigs/pigbreed.htm	Responsible for a "pig" report but this is not available online.

		Milk Producer Organisation				012 843 5600 Provincial information probably available Amount of hectares under irrigation
		Dairy Industry	No trade / flow data		http://www.rediscoverdairy.co.za/	
	Trade flows	SAGIC (South African Green Industries Council)	No publicly available data!		http://lifeisagarden.co.za/home/green-industry-associations/	Umbrella organisation without much data **The South African Green Industries Council (SAGIC)** is an umbrella organisation which represents the consumer green industry throughout South Africa. Its primary objectives are to represent the green industry, defend best practice, organise and market combined networking opportunities, and to promote gardening. Val Wamsteker 011 606 3156
		Interior Plantscapers Association	No publicly data		http://www.ipsa.za.com/	
		South African Landscapers Institute			http://www.sali.co.za/default_sali.asp	
		South African Nursery Association	No publicly available data		http://www.sana.co.za/	Gerdie Olivier Wendy Appel 072 994 5368 / 072 994 5371 Consult Alexis Schaffler' Masters Study
Individual organisations		Phizer			http://www.pfizer.co.za/runtime/popcontentrun.aspx?pageidref=2390&Area=PAH	
		Novartis				

		Karan Beef	Estimates of beef industry		http://www.karanbeef.com/	Feedlots in Heidelberg, Citydeep etc. However, note access to information http://www.karanbeef.com/AccessToInformation
		Denny Mushrooms				To be investigated
		Highveld Mushrooms				To be investigated
		Woolworths				To be investigated
		PicknPay				To be investigated
		Checkers				To be investigated
		Advance				Brian Lever 011 762 5261
		Breweries				
		Enterprise, Escort, Porky, Renown				
		McCain				Ray Smith; rdsmith@mccain.co.za; 082 898 0929
		Tiger Brands				Biggest canning factory
		Parmalat			http://www.parmalat.co.za/index.php?id=38	
		Monsanto				To be investigated
		Topturf				Farms nation-wide; Babsfontein But also transport
		Malanseuns				To be investigated
		Straatoffs				To be investigated
		Retail and wholesale nurseries				To be investigated

Data service providers		SiQ	Agricultural statistics: e.g. high value crops; spatially referenced; farm-level;		http://www.siq.co.za/index.php?option=com_content&task=view&id=37&Itemid=111	Eugene de Preez; Eugene.dupreez@siq.co.za
		GTI GeoTerraImage 2.5m resolution land cover imagery				R80 000
		Quantech			http://www.quantec.co.za/data/easydata-rsa-standardised-industry	GCRO has access
		ESRI				
Existing research & studies		Aliberi research		Expenditure share on food	http://www.hsrc.ac.za/Document-3579.phtml Pg 14	
		A Schaffler Masters study on the value of green infrastructure in Johannesburg				
Useful contacts and experts / professionals in the field		Professor Johan Willemse			University of the Free State	

		Professor Johan Kirtsen			University of Pretoria	