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RESEARCH

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02

CHAPTER 2 RESEARCH

Figure 02: The individuals daily birthright.

2.1 Food Crisis

REAL WORLD PROBLEM

It is estimated that 80% of the world's population will be living in urban centres by the year 2050. (United Nations, 2004)
The increase in urban areas combined with global population growth is resulting in a looming resource crisis, soon we will no longer have safe access to food, drinking water and other basic requirements.

Dickson Despommier, a professor at the Department of Environmental Health Sciences from Columbia University estimates that each individual requires approximately 2.3 litres of water and 1500 calories of food per day to sustain a healthy diet. (Despommier, 2010: 1)

The projected increase in global population will therefore put immense strain on our food and water resources.

THE CAUSES

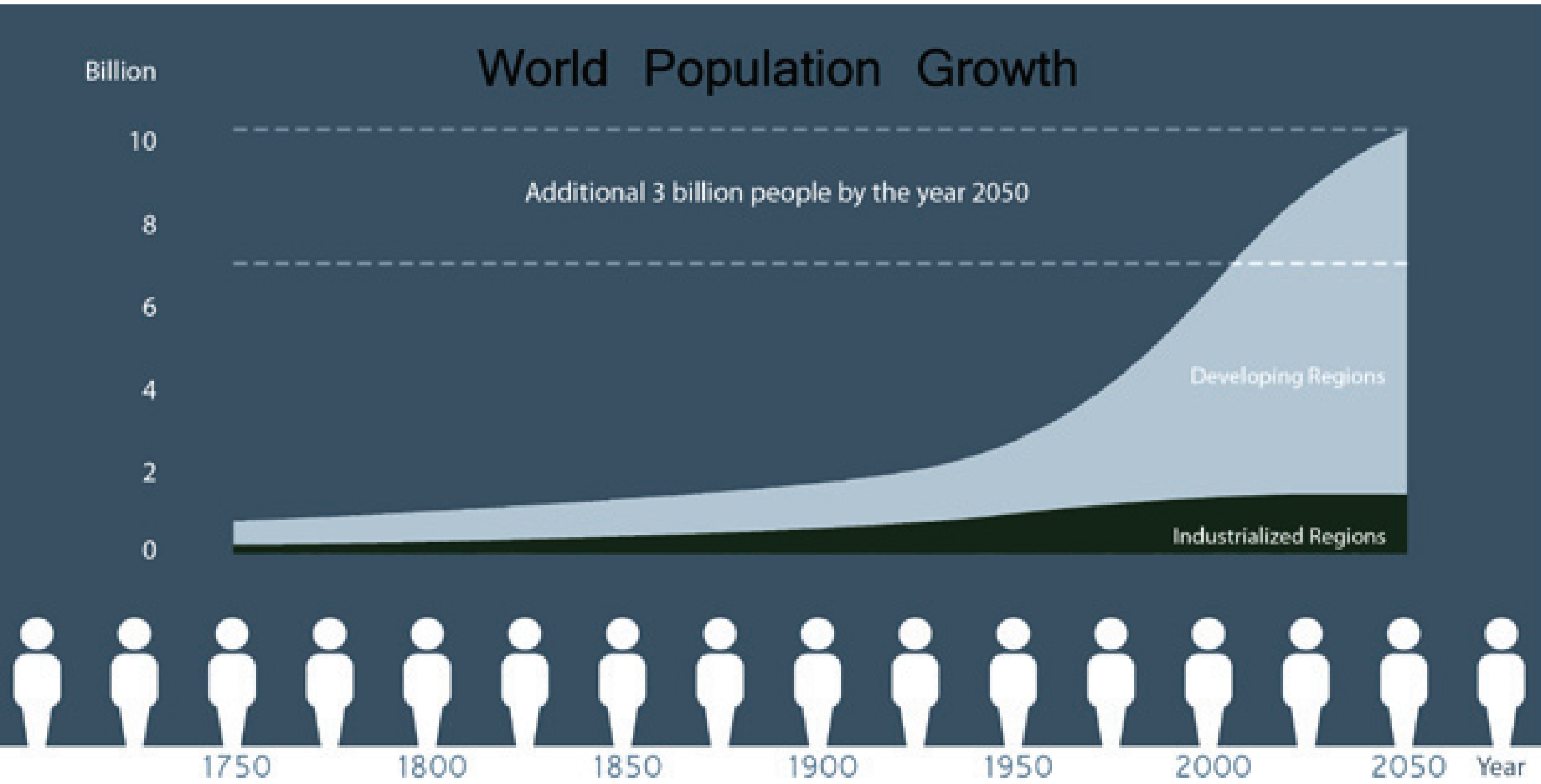
POPULATION EXPLOSION

Figure 04 shows statistics from the United Nations indicating the estimated population growth projected for the future. Current data indicates that global population will increase by approximately 3 billion people by the year 2050.

GLOBAL URBANIZATION

The past few decades has seen a world wide increase in population densities in urban areas. Even though most cities has shown a loss of business from city centres, the steady increase in residential tenants has resulted in a population spike while having a negative effect on the inner city economies. (Pugh, 1997: 49)

Figure 03: Global Population Growth projections.



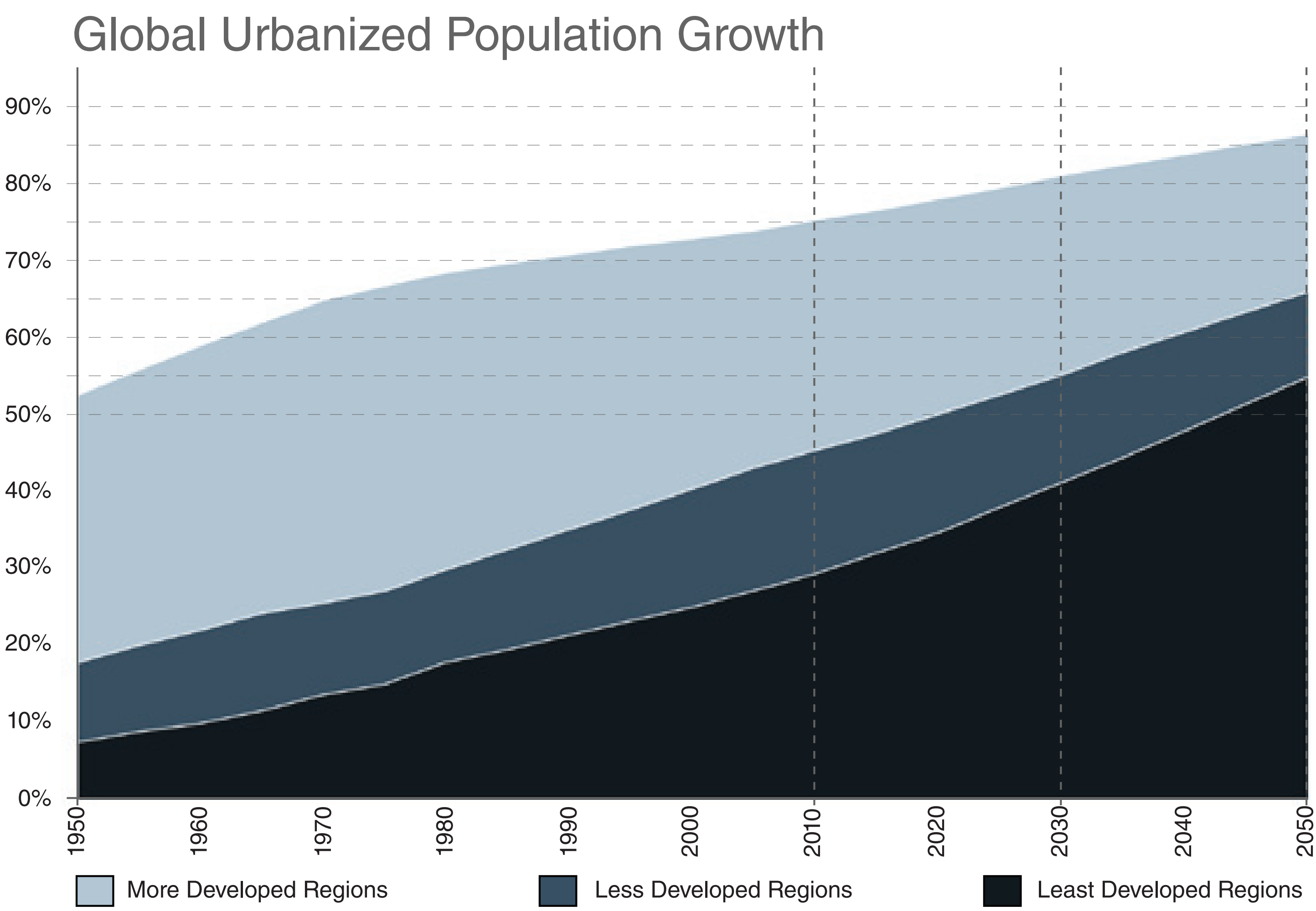


Figure 04: The global urbanization rate by developed regions.

Figure 14 illustrates how in the local context it is estimated that at the current growth rate 60% of Africa's population will be urbanised by the year 2030. (United Nations, 2004)

Statistical data from the South African census indicates an urban population increase from 54% in 1996 to 58% in 2001 (Statistics South Africa: Census, 1996; and Census 2001). This is indicative of the fact that the rate of urbanization in South Africa is currently more rapid than projected for the rest of the world.

PROFILE OF SOUTH AFRICAN URBAN DWELLERS

Most of the urban growth in South Africa is occurring in and around the six major metropolitan areas: Johannesburg-Ekurhuleni, Cape Town, Port Elizabeth, Durban, Pretoria and Vereeniging.
The highest rate of growth is amongst the poorest population typically seeking survival in the informal economic sector. (DEWAR, Dawid, 2003)

By 2050 more than 60% of Africans will be living in cities or suburbs

Illustration 04: Pretoria CBD as an example of African Urbanization.

GLOBAL ARABLE LAND SHORTAGE

As of 2004, approximately 800 million hectares of land were in use for food production – approximately an area equivalent to Brazil , and allowing for the harvesting of an ample food supply for the majority of a human population approaching 6.3 billion. These land-use estimates include grazing lands (formerly grasslands) for cattle, and represents nearly 85% of all land that can support at least a minimum level of agricultural activity. In addition, farming produces a wide variety of feed grains for many millions of head of cattle and other species of domesticated farm animal . (Despommier & Ellingsen, 2008: 1)

Figure 05: Percentage of available arable land currently in use.

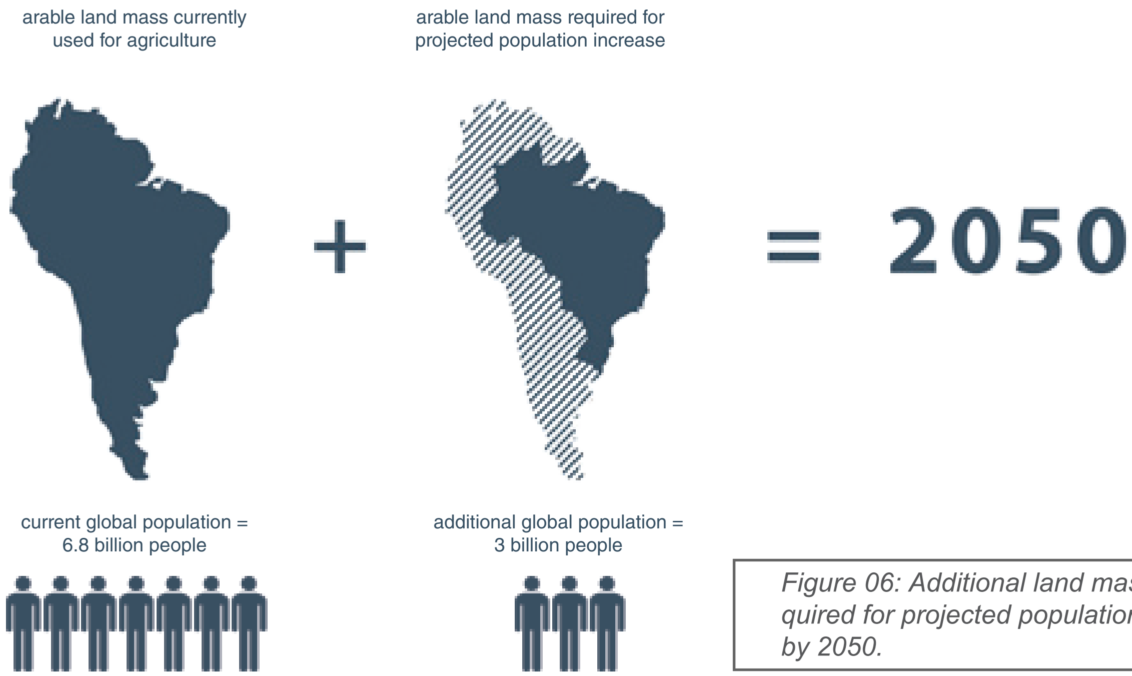


Figure 06: Additional land mass required for projected population growth by 2050.

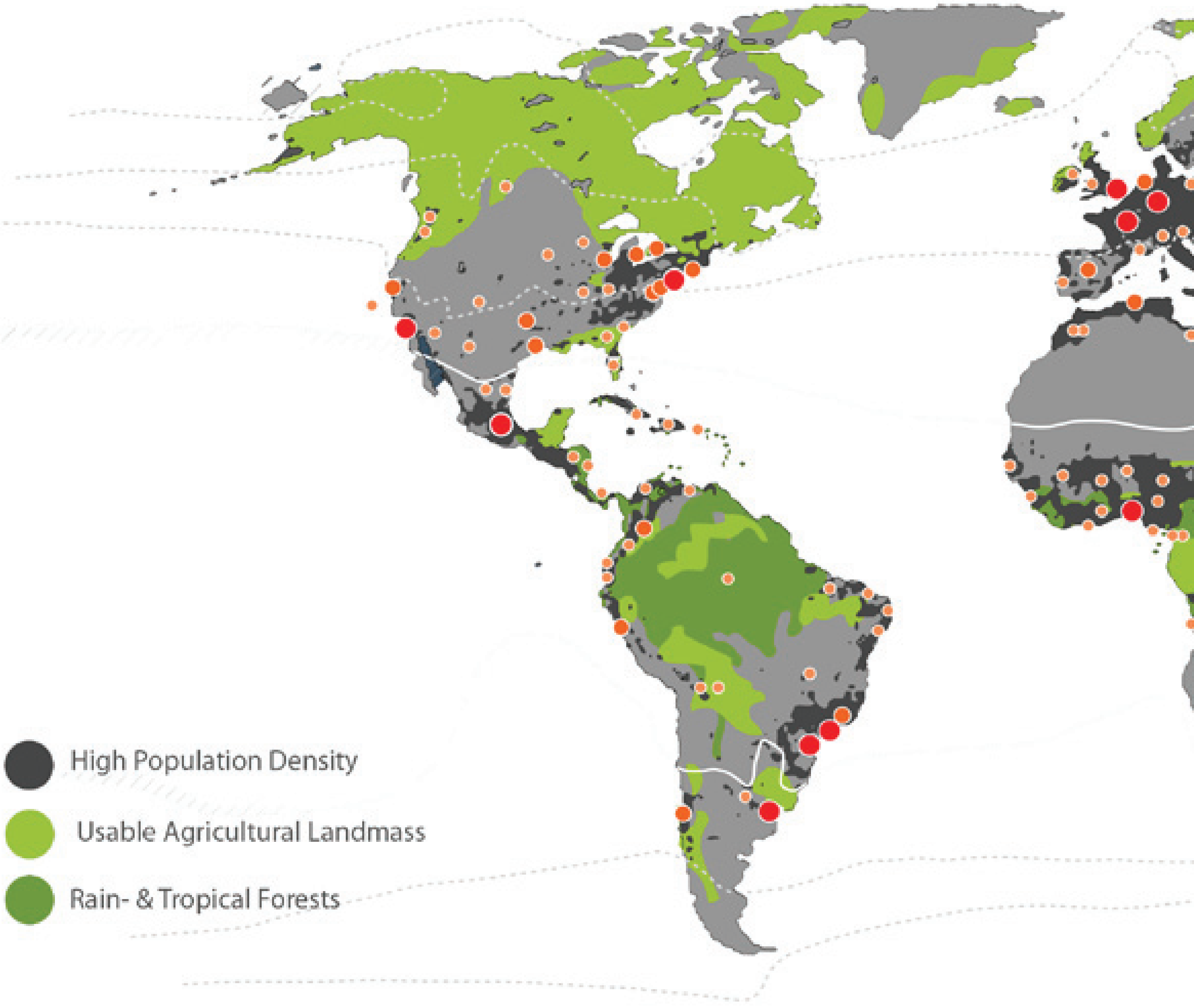
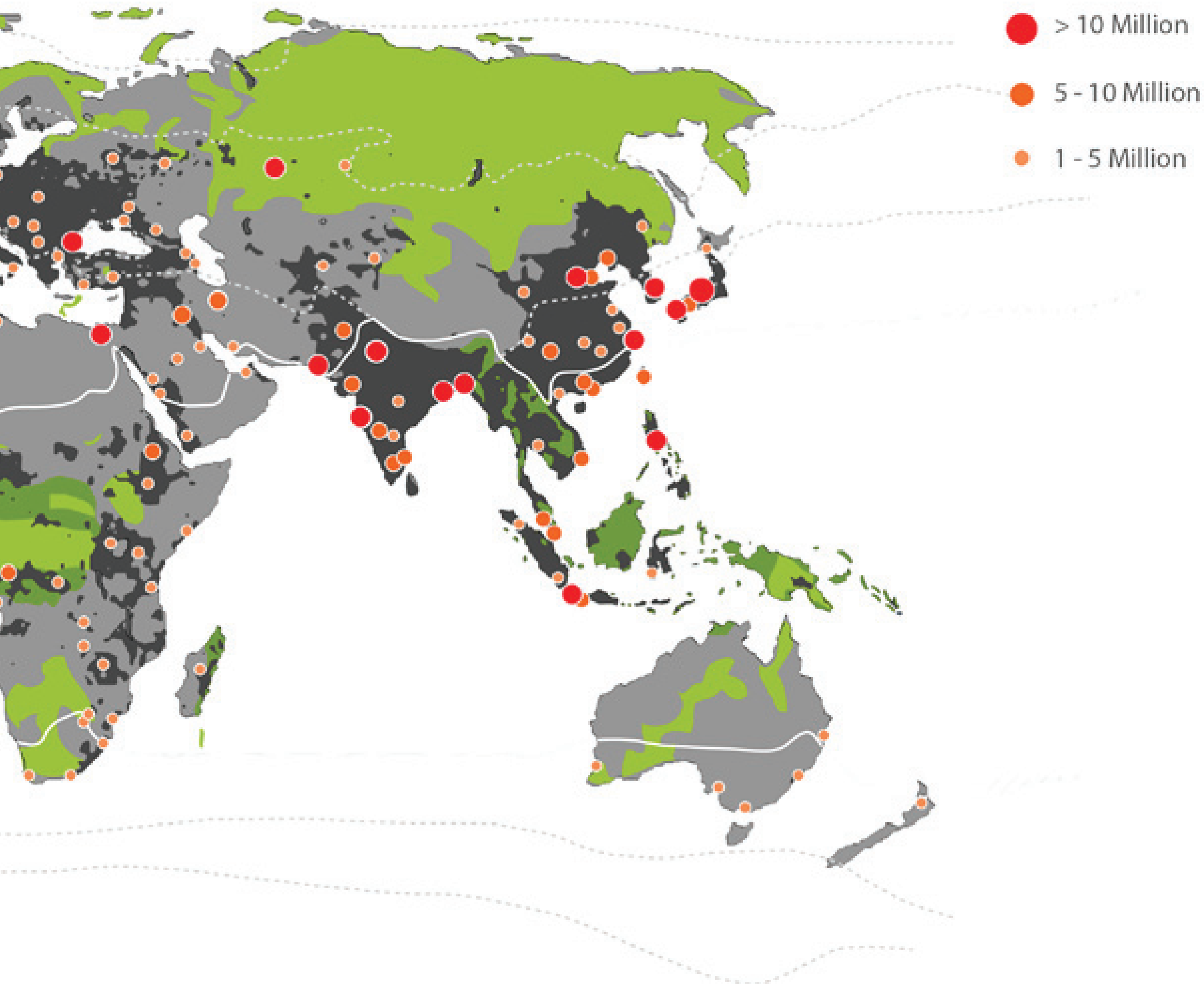


Figure 07: Map showing available arable land worldwide.


> 10 Million
5 - 10 Million
1 - 5 Million

STAPLE FOODS

To address the food crisis an analysis of staple foods found in countries throughout the world is required. This will enable the study to focus on food sources and cultivation processes that can make the biggest impact on this global problem.

The Food and Agriculture Organization of the United Nations (FAO) defines a staple food is one that is eaten regularly and in such quantities as to constitute the dominant part of the diet and supply a major proportion of energy and nutrient needs. (DIOUF, Jacques, 1995)

A staple food alone does not meet a population's total nutritional needs, a variety of foods is required. This is particularly the case for children and other nutritionally vulnerable groups.

Typically, staple foods are well adapted to the growth conditions in their source areas. For example, they may be tolerant of drought, pests or soils low in nutrients. Farmers often rely on staple crops to reduce risk and increase the resilience of their agricultural systems. (DIOUF, Jacques, 1995)

An analysis done by the FAO on proportions of food in average diets around the world indicate that most people live on a diet based on one or more of the following staples: rice, wheat, maize (corn), millet, sorghum, roots and tubers (potatoes, cassava, yams and taro), and animal products such as meat, milk, eggs, cheese and fish.(DIOUF, Jacques, 1995)

Of more than 50 000 edible plant species in the world, only a few hundred contribute significantly to food supplies. Of these only 15 crop plants provide 90 percent of the world's food energy intake, with three rice, maize and wheat contributing two-thirds. These three are the staples of over 4 000 million people.

The Gramineae (cereal) family is the largest staple food group as rice feeds almost half of humanity.

Roots and tubers are important staples for over 1 000 million people in the developing world. They account for roughly 40 percent of the food eaten by half the population of sub-Saharan Africa. They are high in carbohydrates, calcium and vitamin C, but low in protein.

Per caput consumption of roots and tubers has been falling in many countries since the beginning of the 1970s, mainly because urban populations have found it cheaper and easier to buy imported cereals. (DIOUF, Jacques, 1995)

Many countries are experiencing a similar shift away from traditional foods, but there is growing recognition of the importance of traditional food crops in nutrition.

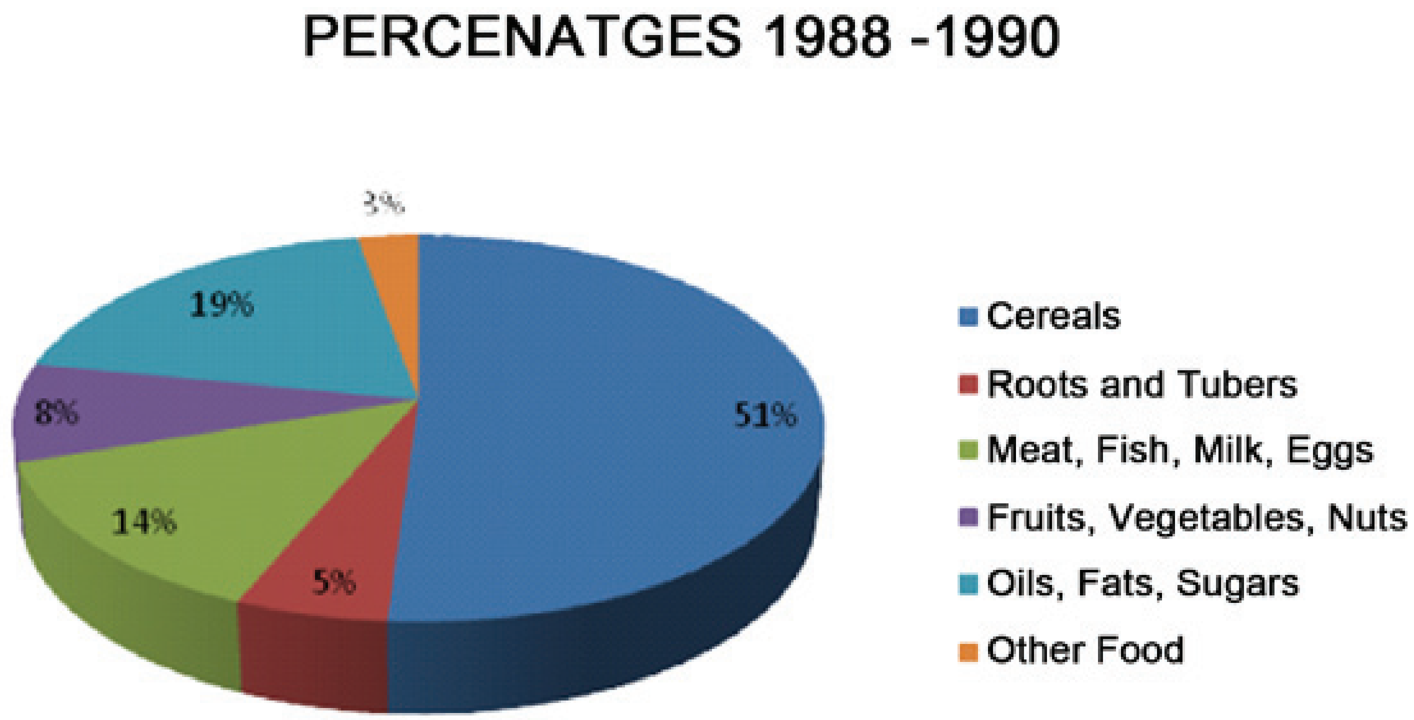


Figure 08: World average diet shown as percentages from 1988 - 1990.

CONCLUSION

Figure 08 shows the average percentages of food sources found in the diets of the global population as per statistical data from the Food and Agriculture Organization of the United Nations (FOA). It is clear from these statistics that edible plant species far outweigh the impact that animal products have on global hunger.

Therefore it seems logical that the focus of the study should be on the cultivation of edible plants as a main area of research or at the very least a departure point.

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2.2 Food as a System

FOOD WEB

The concept of food webs or food cycles was pioneered by Charles Elton in his book, Animal Ecology. A food web consists of a linear sequence of links (collectively known as a food chain) starting from a trophic species that eats no other species in the web and ends at a trophic species that is eaten by no other species in the web. (ELTON, Charles S, 1927)
Figure 09 gives a simple example food web showing how human beings fit into this system.

ECOSYSTEM

An ecosystem is a biological environment that consists of both living (biotic) and nonliving (abiotic) organisms and components that inhabit a particular area. The abiotic components with which the organisms interact include air, soil, water and sunlight.
(CAMBELL, Neil A, 2008)

By definition then human beings form part of their own particular environments and ecosystem.

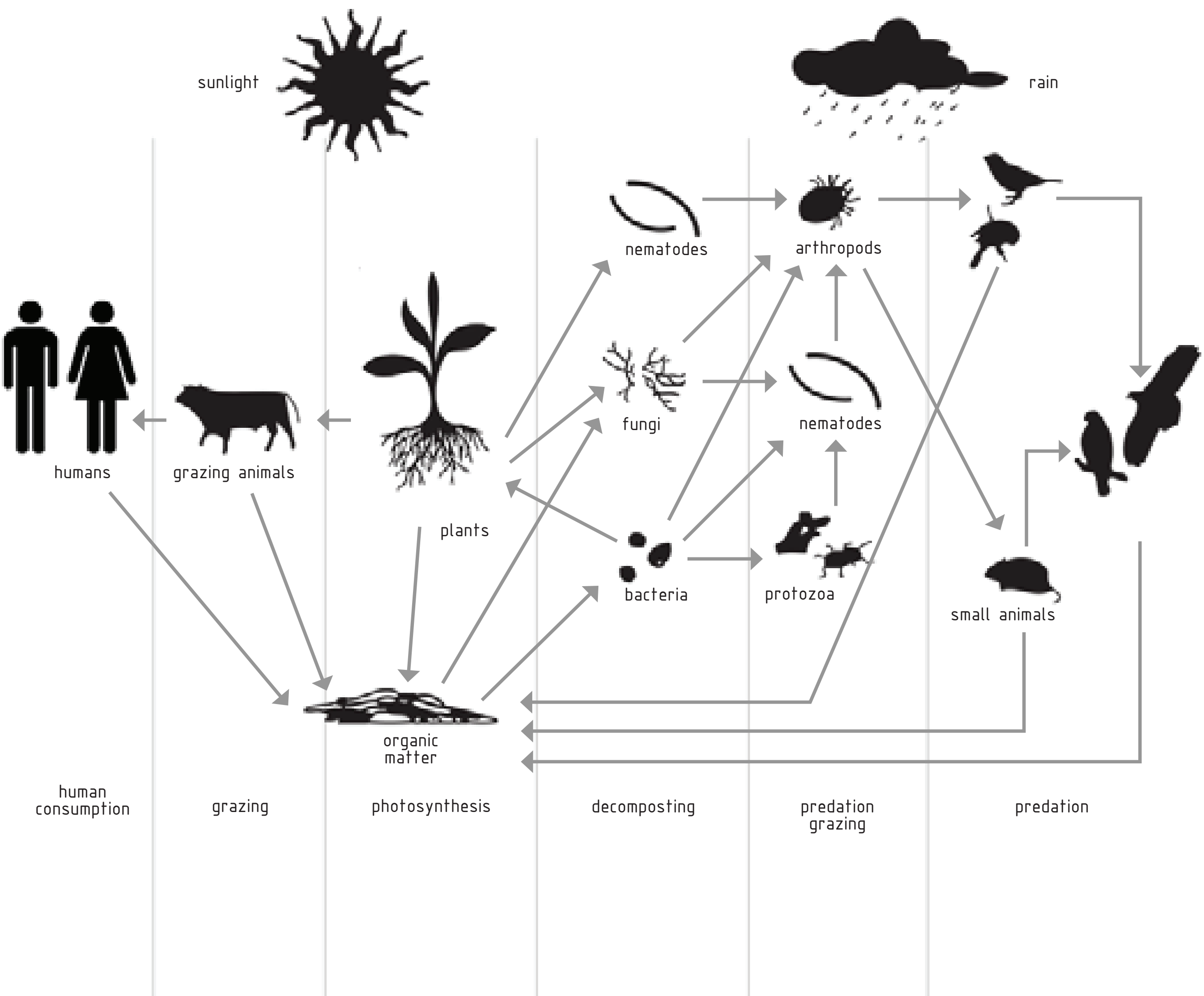

Figure 09: Example of a food web.

PLANT GROWTH SYSTEM

The growing process of plants in their natural environment can be analysed in terms of system design based on inputs, process and outputs:

PHYSICAL INPUTS

- Air (uses CO_2)
- Water (H_2O)
- Plant Nutrients (inorganic mineral salts)
- Energy (Sunlight)
- Anchor (Soil)

PROCESSES

- Osmosis:
  Intake of water and minerals via root system
- Photosynthesis and Respiration:
  Uses light and air to transform water and minerals into organic matter.

OUTPUTS

Organic Matter: Roots, stems, leaves, fruits and seeds.
Gas: O_2

Note:

All energy (sun) and resources required for the plant growth process comes from renewable resources within the ecosystem.

All outputs are returned to the ecosystem and used by other biotic and abiotic organisms and processes. There is therefore zero waste.

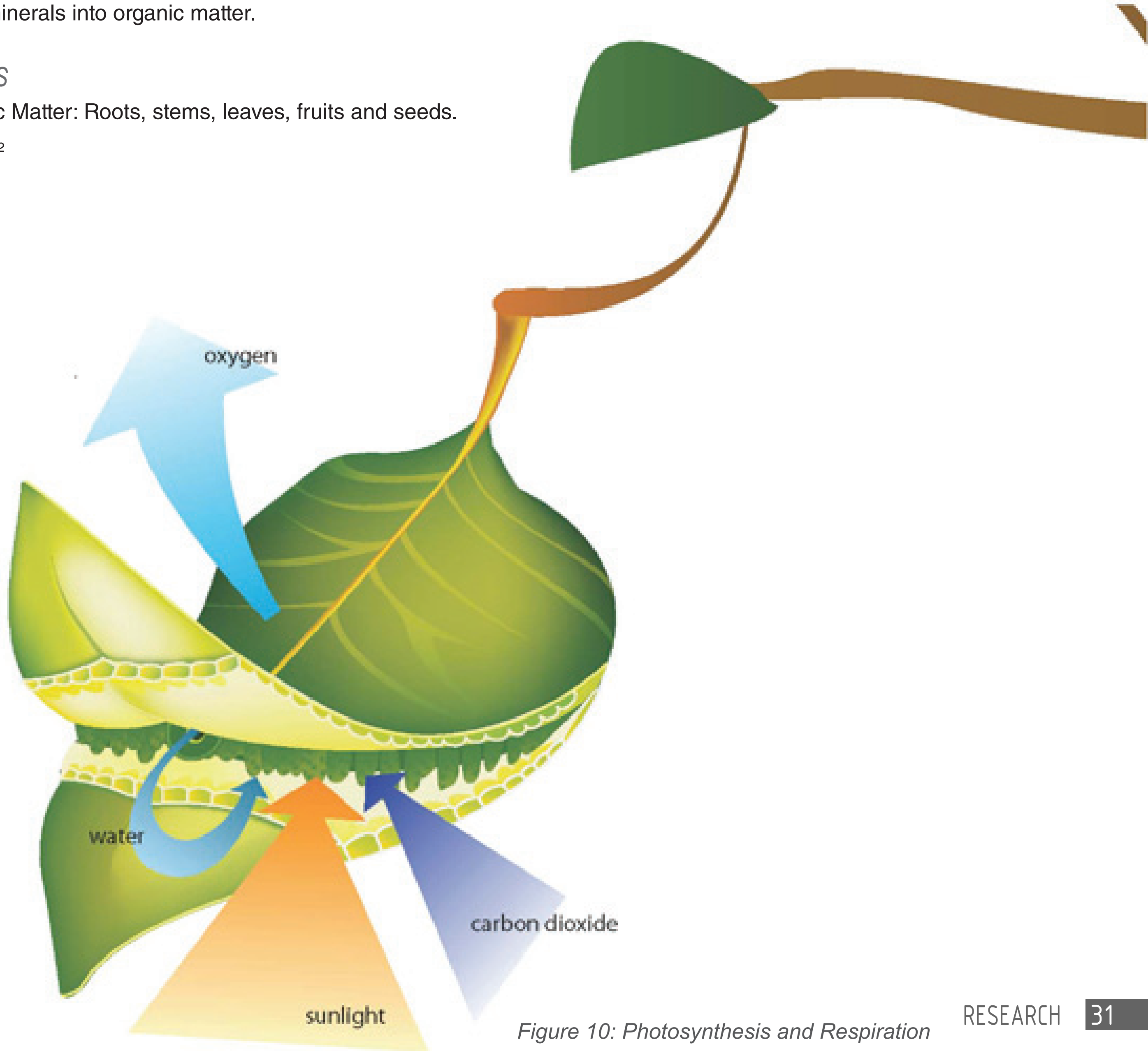

Figure 10: Photosynthesis and Respiration

FARMING SYSTEM

As with the natural plant growth process, farming or cultivation of edible plants can be analysed as a system based on inputs, processes and outputs: (seeFigure 11)

PHYSICAL INPUTS:

Climate
Rain
Temperature
Season
Soil

SOCIO-ECONOMIC INPUTS:

Labour
Rent
Transport Cost
Machinery
Fertilisers
Pesticides
Government Control
Seeds
Livestock
Farm Buildings
Energy (electricity, fossil fuel, etc)

PROCESSES

Planting
Irrigation
Harvesting

OUTPUTS

Crops
Feed

Note:

Agriculture uses large quantities of both natural and man-made resources.

Current agricultural process is responsible for large quantities of waste production that results in pollution of the natural environment and large quantities of agricultural run-off.

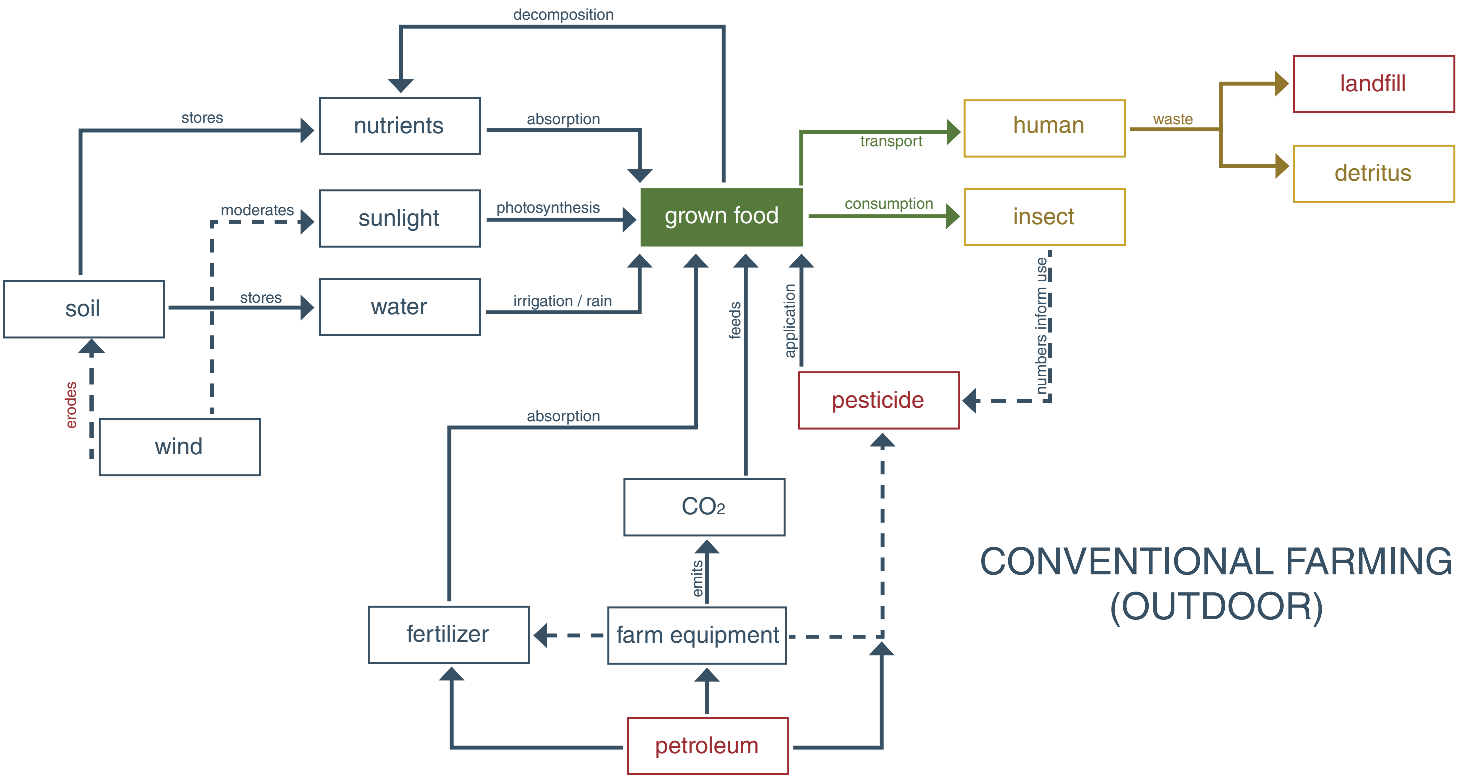

Figure 11: Farming System Diagram

NEGATIVE EFFECTS OF FARMING

Beyond the impact that conventional farming has on resources and waste there are a few more effects that should be mentioned: (BROWN, Katherine H and Carter, Anne, 2003)

EXHAUSTED FARMLAND

The limited reach of current shallow crop rotation practices is woefully underdeveloped and under supported, leaving much of the suitable land available currently for agricultural production infertile or in need of remediation in the years to come.

GEOPOLITICAL POLARIZATION

Developed countries have significantly reduced the areas of land available for their own food supply. These countries are turning to already-strained areas to supplement their own supply. The natural, national resources of a majority of the globe are then stripped away for use by foreign populations, further exacerbating the desperation and conflict in the developing world.

In the long run, this agricultural colonialism is harmful to both the populations it serves, and the populations it exploits. While the developed world loses many of its resources, the industrialized world must pay exorbitantly for shipping costs, and crisis management outside of their legal and sovereign territories. As resources around the world become more scarce, this model of business and international relations will quickly become unsustainable.

SUPPLY CHAIN / PROXIMITY

The proximity of agricultural cultivation to food preparation process and finally to the end user results in high energy demands for processing, storage and transport. These same proximity issues also result in further land loss due to storage requirements.

FLATTENING ECOSYSTEMS

In the developing world, the systematization of the agricultural production has resulted in the homogenization of ecosystems and micro-climates, reducing the overall strength of biodiversity and the resilience of staple food crops.
Modern crops are primarily mono cultured, and not suited to the environment of which they are a part, failing to take advantage of robust local ecologies and their natural systems of irrigation, nutrient cycling, and pest control. This opens the global food supply to vulnerability, making it more susceptible to attack from both existing and yet unknown viruses, fungal infections, and pests.

URBANIZATION / LAND SHORTAGE

For the first time in history, over half of the world's population is living in cities. At the same time, over half of the world is living in poverty. With a severe housing shortage threatening the quality of life and sustainability of rapid urban growth, many communities around the world are turning to the only land left available to them, land which is dangerously unfit for development.
Floodplains and oceanic coastlines are prime targets for informal and illegal settlements. Land here is cheap, and largely deregulated because of the very real threat of impending natural disaster.

PROBLEM STATEMENT

Dickson Despommier compares the bioshpere with the techno-sphere and notes the difference between the cyclical nature of the bioshpere (cradle to cradle) when compared to the linear nature human processes (cradle to grave).

Ecological observations and studies, beginning with those of J. Teal in Georgia (Teal, 1962) showed how living organisms behave with regards to the sharing of limited energy resources. Tight knit assemblages of plants and animals evolved into trophic relationships that allowed for the seamless flow of energy transfer from one level to the next, regardless of the type of ecosystem in question (Ricklefs, 2000). In fact, this is the defining characteristic of all ecosystems.

In contrast, humans, although participants in all terrestrial ecosystems, have failed to incorporate this same behaviour into their own lives.

Instead of living in harmony with the natural environment, human beings have resorted to systems of control and domination of the biosphere.
Smout Allen describes the countryside as "under the influence of nature but under the control of man"
He remarks that previously natural landscapes have taken on a artificial patination and a utilitarian topography. (Smout Allen)

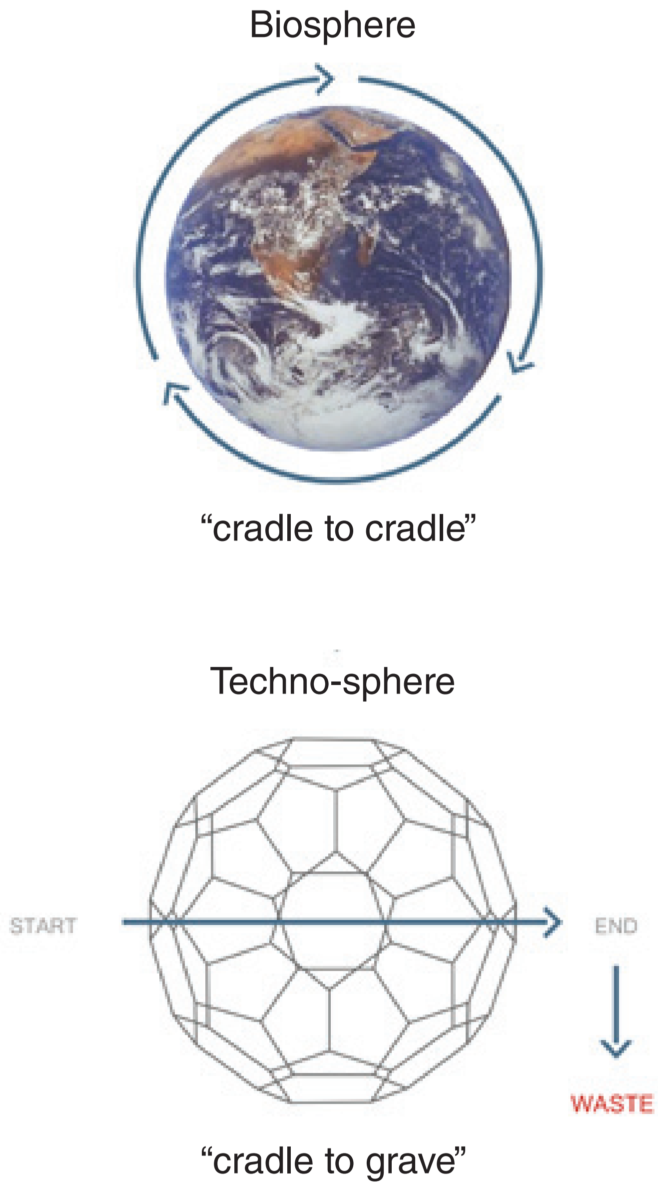

Figure 12: Comparison between biosphere and techno-sphere.

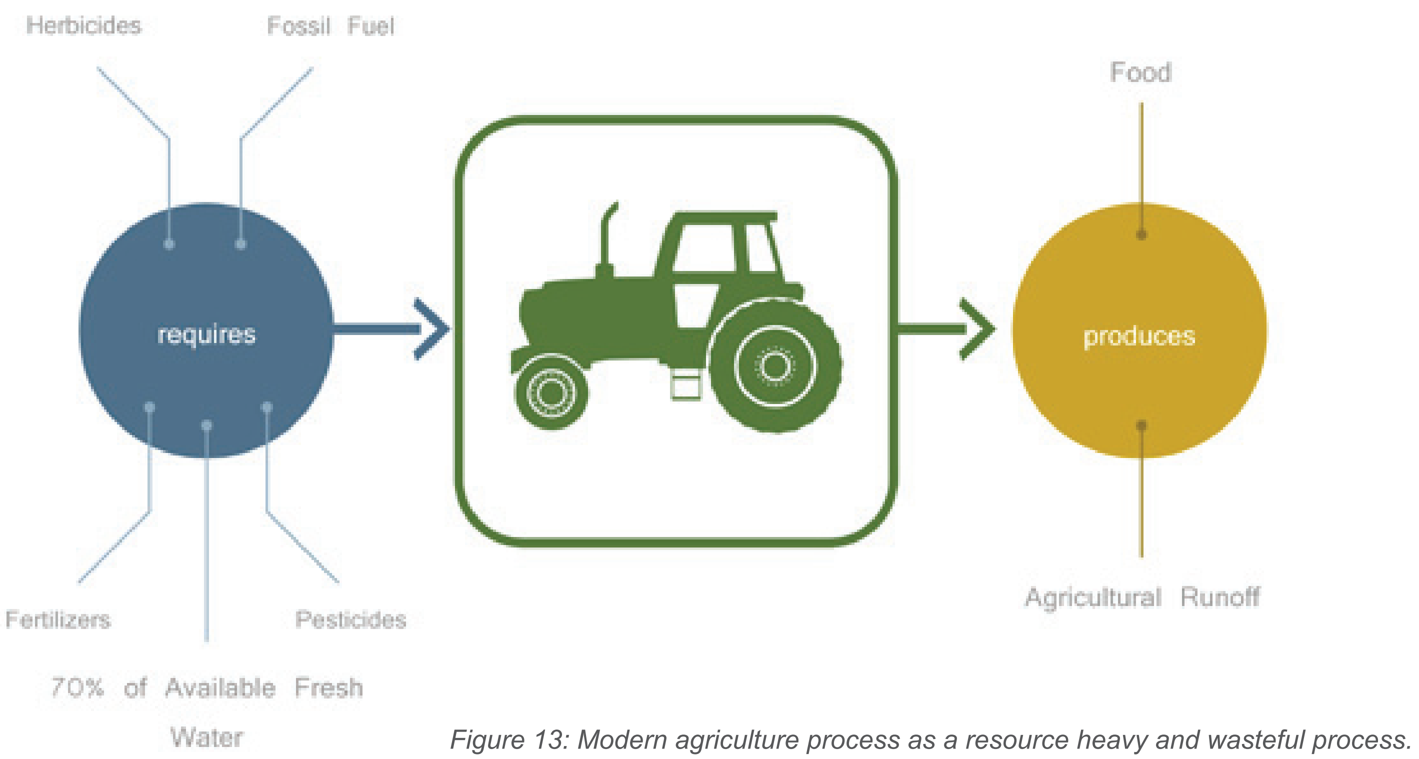

Figure 13: Modern agriculture process as a resource heavy and wasteful process.

Illustration 05: The future of the world in our hands.

CONCLUSION

Two spatial problems can be deduced from the study of the expected food crisis. On of proximity to end user and available arable land.

By exploring the use of urban land for agriculture strain can be taken of the traditional farming sector. This concept of urban farming would reduce the need for arable land and shorten the supply chain between food production and consumption.

Urban farming can be explored both in terms of productive urban landscapes as well as building integrated agriculture.

2.3 Urban Agriculture

URBAN FARMING METHODS

Urban agriculture can be explored in terms of productive urban landscapes and productive architecture or building integrated agriculture: (BROWN, Katherine H and Carter, Anne, 2003)

PRODUCTIVE LANDSCAPES

- Allotments
- Community Gardens
- Urban Garden Agriculture

PRODUCTIVE ARCHITECTURE

- Green Wall
- Green Roof
- Balcony Farming
- Greenhouse
- Vertical Farming

Due to the nature of this study (architecture) the exploration will focus mainly on the relationship between buildings and agriculture however it should be noted that productive landscapes can play a vital role in the integration of farming into an urban setting.

ARCHITECTURE AND FARMING

The concept of cultivated plants being integrated into buildings is not a novel idea, early examples of this practice can be traced as far back as 601 BC to the Hanging Gardens of Babylon.

Today man made structures or greenhouses are used to enclose crops in areas of the globe where climatic conditions are not ideal for their cultivation. Greenhouses rely on maximum light transmittance through a mostly transparent skin making it less ideal for use in an urban setting where overshadowing is common and multistory structures often required to maximize developed area.

Greenhouse systems make use of both soil-based (plants using soil as growth medium) and soil-free (plants roots supported by a substance other than soil) systems. (VON ZABELTITZ, Christian, 2011)

Some ad-hoc methods include greens walls, green roofs and balcony farming. The benefit of these systems is that they can be added to existing buildings or designed into proposed structures as a productive component. Yields from such systems would generally be comparatively low and the care and harvesting of crops can conflict with other building programs.

The most intensive and productive of the methods is the concept of vertical farming, this involves large-scale agricultural production in multistory buildings or any vertically inclined surface.
It is an intensive farming strategy which mainly employs advanced techniques such as hydroponics and aeroponics to produce crops like fruits, vegetables and edible mushrooms continuously. This method has the added benefit of maximizing productive area by multiplying the usable floor space.
(DESPOMMIER, Dickson, 2010)

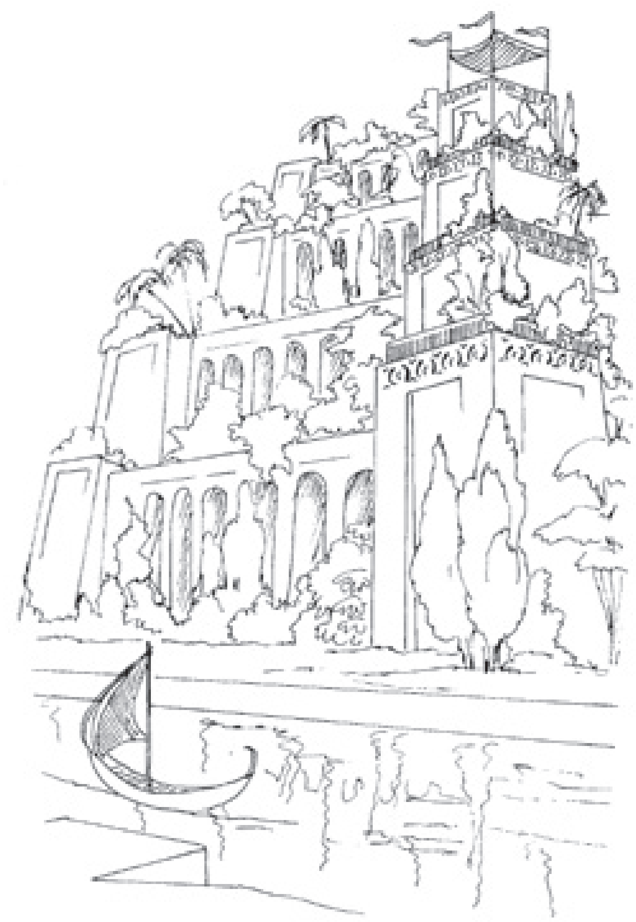

Figure 14: Artists impression of The Hanging Gardens of Babylon

VERTICAL FARMING

As early as 1974 John Hix documented some of the first built examples of vertical farming in his book The Glass House.
Koolhaas wrote in his 1978 publication, Delirious New York, about "The skyscraper as Utopian device for the production of unlimited numbers of virgin sites on a metropolitan location". (1994, 82)

Ken Yang proposes the use of vertical integrated agriculture to serve as decentralized food production units that serves and is linked with groups and communities in a city. His award winning skyscraper Menara Mesiniaga (built 1992) serves as an example of the integration food production with living units

In 1999 the American ecologist Dr. Dickson Despommier developed his own concept of the vertical farm focused primarily on the scaling up of soilless cultivation methods like hydroponic and aeroponic farming.

These methods require less space and water than traditional farming and is therefore ideally suited for indoor farming. Due to the limitations of natural light in multistory buildings it can be assumed that most vertical farming proposals will have to make use of artificial grow lights adding to the energy consumption of the process.

Despommier argues that these and other energy demands can by negated by including energy saving techniques, renewable energy sources and by offsetting them with reductions in transport, water and pesticide use. (DESPOMMIER, Dickson, 2008)

Figure 15: "The Living Skyscraper: Farming the Urban Skyline" by Blake Kurasek

BENEFITS OF VERTICAL FARMING

Despommier and Eric Ellingsen lists the benefits of vertical farming in their 2008 essay The Vertical Farm: The sky-scraper as vehicle for a sustainable urban agriculture. (DESPOMMIER, Dickson, 2008)

- Year-round crop production
- Eliminates agricultural runoff
- Significantly reduces use of fossil fuels (farm machines and transport of crops)
- Makes use of abandoned or unused properties
- No weather related crop failures
- Food grown organically employing chemically defined diets specific to each plant and animal species: no herbicides, pesticides, or fertilizers.
- Uses 70% less water.
- Converts black and gray water to drinking water
- Adds energy back to the grid via methane generation
- Creates new urban employment opportunities
- Fresh produce supply for urban dwellers.
- Reduces the risk of infection from agents transmitted at the agricultural interface
- Returns farmland to nature, helping to restore ecosystem functions and services
- Controls vermin by using restaurant waste for methane generation

SOILLESS FARMING

The vertical farming concept promotes the use of soilless farming methods. These include Hydroponics, Aeroponics and Drip Irrigation. (see Illustration 06)

Hydroponic and aeroponic technology has increased yield potential by more than 23 times while decreasing water usage by well over 30 times when compared to traditional farming methods. (KENYON, Stewart, 2002)
Advances in artificial growing light technologies have meant the production of low energy LED's and sulfer-microwave lamps that can now be used as alternative light sources in agricultural environments.

SOILLESS FARMING METHODS

- HYDROPONICS –Nutrient rich water flows through plant roots
- AEROPONICS –Nutrients are sprayed onto roots
- DRIP IRRIGATION - Nutrient rich water is dripped onto growth medium.

Illustration 06: Soilless Farming Methods

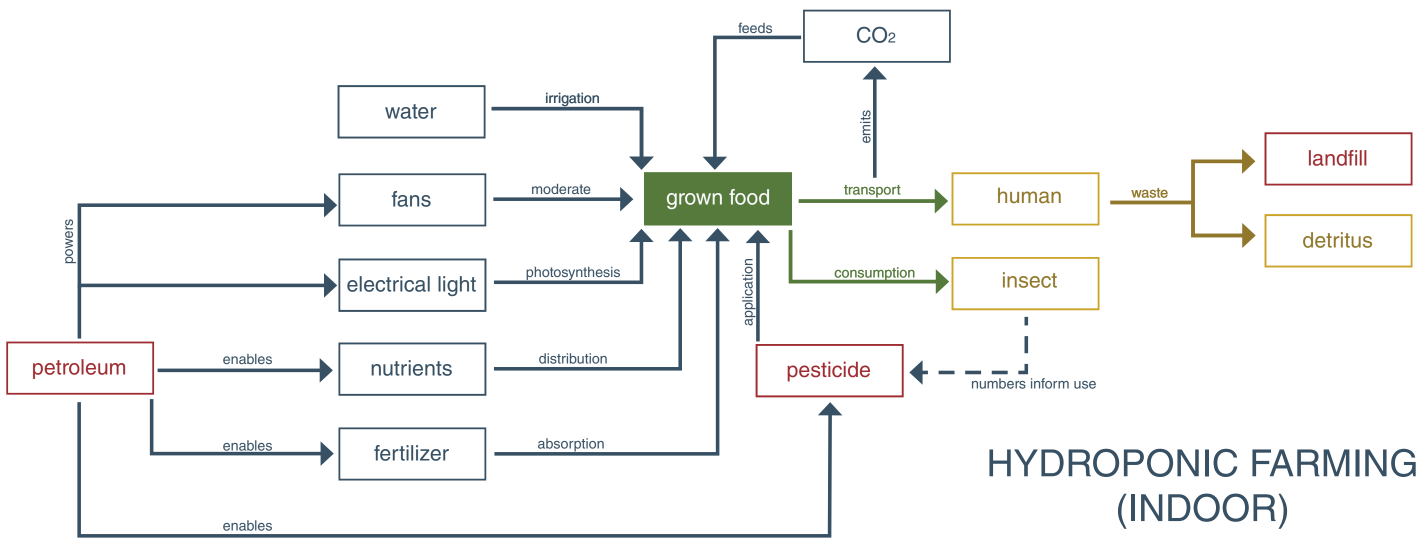

Figure 16: Hydroponic Farming system diagram (indoor).

FARMING IN A BALANCED SYSTEM

Figure 16 illustrates the resources and energy required by a hydroponic system. Even though resource usage has been reduced when compared to traditional farming this is still a linear system (cradle to grave).

By mimicking the principles found in the study of natural ecosystems it is possible to construct a food production system that requires less energy and resources and produces zero waste.

A simple example of this is a system called aquaponics. This refers to a combination of hydroponics and aquaculture (fish farming). (see Figure 17)

More than 50% of the waste produced by fish is in the form of ammonia, secreted through the gills and in the urine. The remainder of the waste is excreted as faecal matter, undergoes a process called mineralization which occurs when Heterotrophic bacteria consumes fish waste, decaying plant matter and uneaten food, converting all three to ammonia and other compounds. In sufficient quantities ammonia is toxic to plant and fish. Nitrifying bacteria, which naturally live in the soil, water and air convert ammonia first to nitrite (Nitrosomonas bacteria) and then to nitrate (Nitrobacter) which the plants consume. Nitrifying bacteria will thrive in the gravel beds and in the water in the system. The plants readily take up the nitrites and nitrates in the water and, in consuming it, help to keep the water clean and safe for the fish.

The aquaponics system can be expanded to include a vermicomposting component using earthworms. Worm farms have recently become a popular addition to many gardens, balconies and kitchen in South Africa. The attraction being a easy way of disposing of biodegradable waste (food waste) without too much mess or maintenance involved.
(KENYON, Stewart, 2002)

Within the aquaponics systems the worm farm adds the additional benefit of producing feed for the fish in the form of worm larvae because the adult worms can be fed using food waste from local restaurants this system even reduces waste of external systems.

The result is a “near closed” cycle that relies on minimal external input to stay operational.

Power

Biodegradable Waste

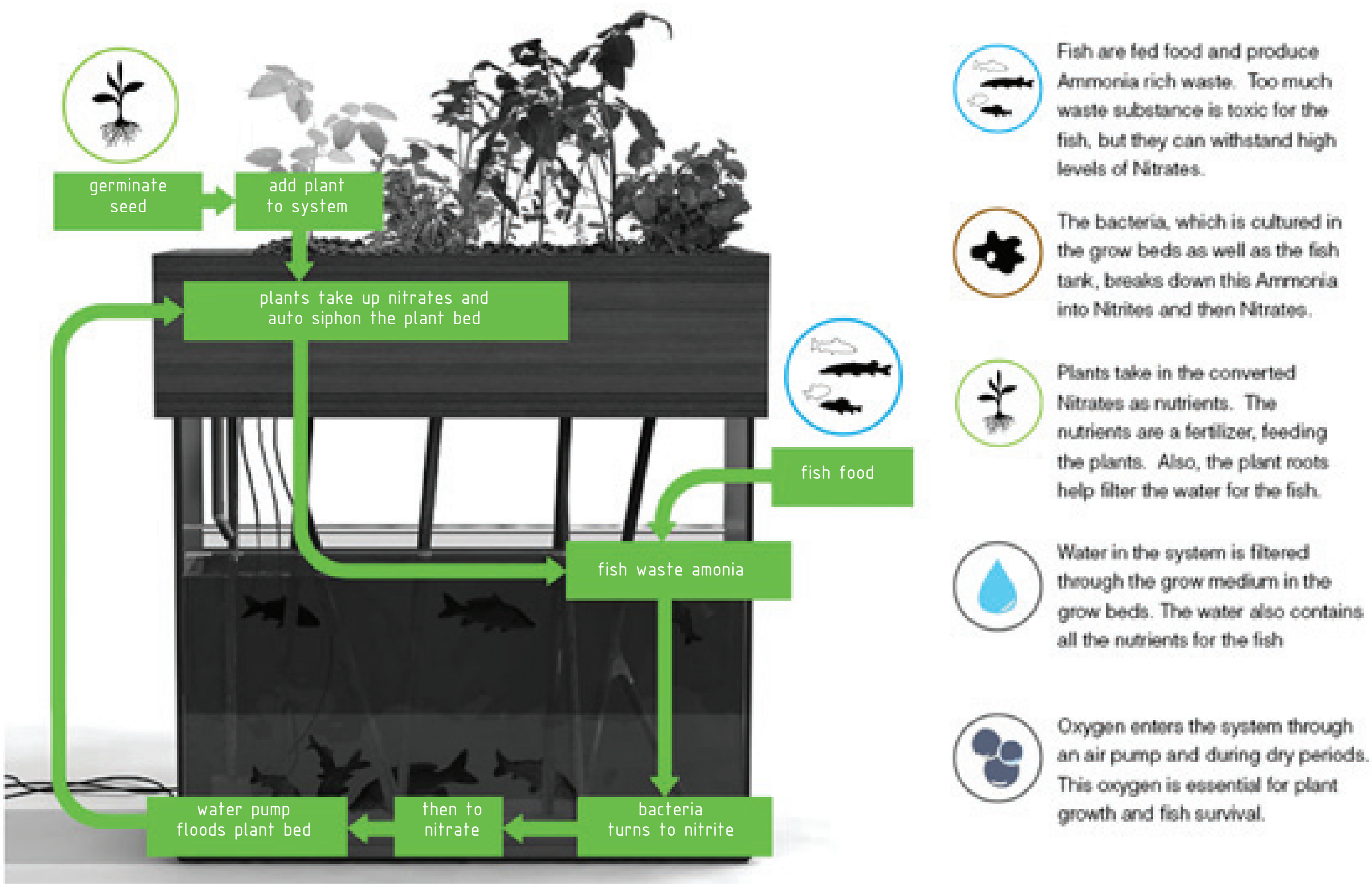

Figure 17: A diagramatic explanation of aquaponics.

Figure 18: A diagramatic explanation of a "cradle to cradle" farming system.