TRAINING MANUAL

- ENVIRONMENTAL MANAGEMENT -

WASTE MANAGEMENT

COLEACP

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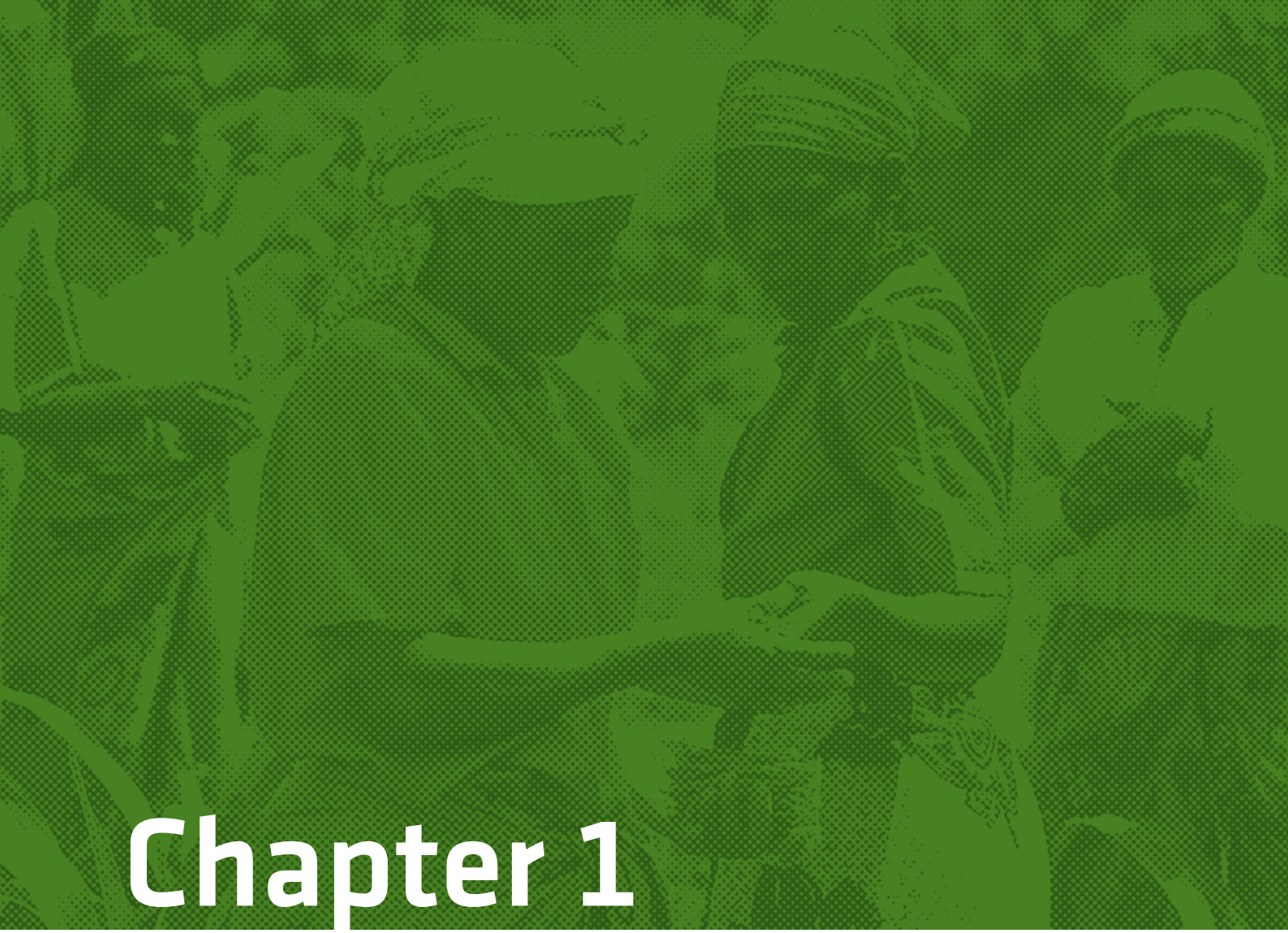
FIT FOR MARKET

WASTE MANAGEMENT



Chapter 1

Introduction: Definitions of waste and waste classes

1. INTRODUCTION: DEFINITIONS OF WASTE AND WASTE CLASSES

1.1. Introduction to the problem of waste

According to United Nations Environment Programme (UNEP) we are today producing 2.12 Billion tonnes of waste every year, of which 1.3 billion tonnes of waste is generated in urban areas alone. The World Bank estimates that the average amount of waste generated by person to 1.2kg per day, but the volume and type of waste varies widely between regions and income bands. In lower income countries each person produces 0.60kg of waste a day, whilst in the higher income countries this rises to 2.13kg a day.[1] By 2025, it is expected that as population grows and people become more affluent, waste generation in cities alone will rise to 2.2 billion tonnes a year.[2]

A summary of the most pressing global issues associated with waste are:

- **Unsustainable waste levels:** Solid waste generation will increase by 70% from 2010 levels of 3.5 million tonnes per day to over 6 million tonnes by 2025. The waste from urban areas alone is already enough to fill a line of trash trucks 5,000 km long every day. Research suggests that by 2100 a growing urban population will produce three times as much waste, with widespread social and environmental consequences for cities around the world.[3]

- **Disposal of waste:** Unregulated or illegal dump sites serve about 4 billion people and hold over 40% of the world's waste.[4] Operating waste disposal services requires integrated systems that are efficient, but more than half the world's population does not have access to regular waste collection. Research suggests that low and middle income countries infrastructures (waste sorting and treatment facilities, closed dumps, landfills, bins, dumpsters, trucks and transfer stations) are already stretched and insufficient to serve a growing urban population. Lack of effective waste management systems, as well as practices related to unregulated dumps or open burning have serious health, safety and environmental consequences. Uncollected solid waste contributes to flooding, air and water pollution and has potential public health impacts such as respiratory ailments from burning, and diarrhoea and dengue fever from open air dumps. Poorly managed waste sites serve as a breeding ground for pests and diseases.

1 World Bank, "What a Waste: A Global Review of Solid Waste Management" 12 March 2012, Figure 6- 8, Page 11- 18 www.siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

2 World Bank, "Solid Waste Management" 7 April 2017, www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

3 World Bank, "Global Waste on Pace to Triple by 2100" 30 October 2013 www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple.

4 World Bank "Waste Not, Want Not – Solid Waste at the Heart of Sustainable Development." March 2016. www.worldbank.org/en/news/feature/2016/03/03/waste-not-want-not---solid-waste-at-the-heart-of-sustainable-development.

- **Climate Change:** As organic material such as food scraps break down in landfill, it releases methane (a greenhouse gas 21 times more potent than carbon dioxide) accounting for 12% of total global methane emissions and almost 5% of total greenhouse gas emissions.[5] This makes waste disposal the fourth largest source of non-carbon dioxide GHG. Carbon dioxide from biomass organics in municipal waste are considered climate neutral. This is because the carbon emitted when plants are burned or allowed to biodegrade is equal to the carbon absorbed during growing. The carbon in biomass will return to the atmosphere regardless of whether it is burned for energy, allowed to biodegrade or lost in a forest fire This includes CO2 from composting (aerobic) as well as burning of methane in a flare or a generator to produce electricity.[6]

- **Costs of managing waste:** According to the World Bank population growth and higher consumption levels mean that the costs of dealing with waste will rise from $205 billion a year in 2010 to $375 billion by 2025. Given that in developing countries solid waste management can consume up to 50% of a municipality's budget, those countries on the verge of transitioning from low to middle income status, will be hit particularly hard, with no tax or fee structure to sustain solid waste programmes and a population accustomed to using free, open air dumps.[7]

- **Social impact of waste:** Waste industries around the world rely on informal workers, where 15% to 20% of the waste is managed by individuals or micro enterprises that are not formally registered or recognised.

- **Food loss and waste:** For the horticultural industry, waste is a particularly important issue. FAO estimates that roughly 1.3 million tonnes of food, one third of the global food produced for human consumption is lost or wasted every year. 30% of loss and waste is for cereals, 40%-50% for root crops, fruits and vegetables, 20% for oil seeds, meat and dairy.[8] At the consumer level, the yearly food waste estimate per capita is between 95-115kg in Europe and North America, and between 6kg-11kg a year in sub-Saharan Africa and South Asia.

5 "The growing global landfill crisis" http://steelysdrinkware.com/growing-global-landfill-crisis/.

6 C.Peterson, C.Barrera, Z.Azizova "A look at World Bank projects designed to reduce the climate change impacts of waste management in developing countries." www.waste-management-world.com/a/waste-and-the-world-bank.

7 World Bank "Waste Not, Want Not – Solid Waste at the Heart of Sustainable Development." March 2016. www.worldbank.org/en/news/feature/2016/03/03/waste-not-want-not---solid-waste-at-the-heart-of-sustainable-development.

8 FAO, "Save Food: Global Initiative on Food Loss and Waste Reduction: Key facts on food loss and waste you should know".2017. www.fao.org/save-food/resources/keyfindings/en/.

- **Waste of limited natural resources:** A growing population means that there will be a growing demand for agricultural products. It is estimated that it takes 2,000 to 5,000 litres of water to produce the average daily food intake of one person.

  Research by the OECD (2015) suggests that we will have to produce almost 50% more food by 2030.[9] Research by the OECD (2015) suggests that we will have to produce almost 50% more food by 2030. Growing concerns around soil erosion, water scarcity, degraded lands and ecosystems, means that we cannot afford to lose or waste food. These global issues imply that we need to become much more resource efficient, and look at options for reducing and reusing waste. This is relevant for all sectors of the economy, but especially for agriculture given current food loss and waste globally.

1.2. Definition of waste

Waste is defined **as any substance, material or object that is unwanted, or unusable and which is discarded or disposed of after it's primary use.** The OECD states that waste may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products and their final consumption. Waste can be broken down into 4 principal classes:[10]

1. **Biological waste:** containing mostly natural organic materials (remains of plants, animal excrement, biological sludge from waste-water treatment plants and so forth). Biological waste can take both solid and liquid waste form and can also come from household waste.

2. **Household waste:** referring to waste material usually generated in the residential and urban areas. Including waste with similar characteristics which is generated in economic activities that can be treated and disposed of together with household waste. The composition of household waste tends to be biological and can also include solid waste.

3. **Industrial waste:** such as liquid, solid and gaseous wastes originating from the manufacture of specific products.

4. **Solid waste:** Solid wastes include municipal garbage, can include hazardous materials such as industrial and commercial waste, sewage sludge, wastes resulting from agricultural and animal husbandry operations and other connected activities, demolition wastes and mining residues.

9 OECD, 2015, www.oecd.org/agriculture/water-use-in-agriculture.htm.

10 OECD "Glossary of Statistical Terms" www.stats.oecd.org/glossary/detail.asp?ID=2896.

Within a horticultural context, waste occurs at every stage of the food production process. For the purpose of this manual we will look at waste from two angles. Firstly, the waste derived from the direct activities linked to the horticultural product from pre-harvest to consumption E.g. biological waste on the farm, solid waste such as plastic materials used for packaging. Secondly, food loss and waste derived from surplus production or inefficient harvesting, processing, storage, distribution and consumption of horticultural produce.

1.3. On farm waste

On farm waste types range from the biological (crop and animal residue) to household waste (kitchen, plastic waste, paper) and solid waste (metals, empty chemical containers and fertilizer bags).

Effective integrated waste management on farms requires producers to identify the types of waste generated and to reduce their impact on people and the environment through its effective disposal, reuse or recycling. For example, on the farm any holes dug to deposit waste should be far from water sources and rainwater should not be allowed to collect into deposits. Additionally, any waste water used in processing of food which is dispersed directly into water bodies can impact on the watershed for entire communities who could find themselves drinking polluted water. It is essential to raise awareness on the farm about different processes and safe waste management, to ensure an efficient waste disposal system.

On farm waste can effectively become a resource to be used again. To facilitate this, it needs to be separated and clearly divided into different categories, such as paper, metals, organic wastes and plastics. Inorganic wastes cannot be broken down, but can be used for different purposes on farm and in the household. However, any waste that is mixed up and not segregated cannot be used again.

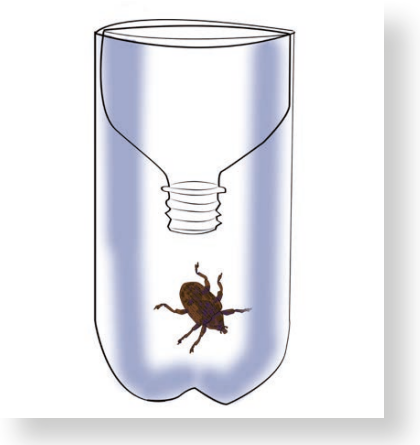


Figure 1: An insect trap using recycled large plastic bottles which are painted red to attract insects.

1.3.1. Organic wastes for composting

Organic wastes from the farm can be used to make compost which added to the soil, improves soil fertility. Composting is the microbiological decomposition of organic substrates in the presence of oxygen (aerobic conditions).

Kitchen waste, fruit pulp, cocoa pods, banana stems, dropped or diseased fruits can all become fertilisers once composted, reducing the need for the purchase of chemical fertilizers. Animal excrement derived from poultry to cattle can also be used to make manure and added as a fertilizer. In a typical composting process, 40-70% of the organic material present is degraded, with the output weight of the compost being 30-50% of the input weight. For manure, dry solids contents of minimum 30-40% are required to allow effective composting. Branches and leaves can be used to make mulch material that helps to provide cover and retain moisture in the soil.

1.3.2. Disposal of waste and hazardous materials

Poorly managed waste programmes, such as open air burning and leachates from open dumps not only contribute to climate change, but also contribute significantly to water and soil contamination. There are notable hazards for both humans, wildlife and biodiversity. When disposing of hazardous waste in recycling companies or municipal waste areas, one must ensure that the waste operators are disposing of waste responsibly, and that they are not dumping waste into the environment or incinerating it illegally. One way to do this, is to check that the site has waste operating permits.

1.3.3. Burning waste

Burning waste (including leaf cuttings or grass clippings) contaminates air, soil and damages human health from toxic gases. Using an incinerator to burn waste is only permitted if there is technical data that the incinerator reaches temperatures high enough for toxic fumes not to be generated.

There are various low cost options available to farms which wish to install incinerators. These have been developed by organisations such as Sustainable Sanitation and Water Management (SSWM) and Practical Action, and notes for construction are publicly available.[11] Training on the handling of incinerators is essential.

These must be built away from living quarters and the farm should hold permits that allow the legal and safe operation of the incinerator. Waste such as plastic agrochemical containers, should not be re-used as household containers, thrown away or burnt, but instead washed and perforated to ensure they cannot be reused.

Figure 2: Design Principles (Small-scale) incinerator.
Capacity:
• Small loads (12-100kg an hour).
• Requires small sized waste or it has to be shredded before.
• Can be built with locally available material.
Source: SSWM Toolkit[12]

11 Practical Action, "Low Cost Construction Notes" www.answers.practicalaction.org/our-resources/item/low-cost-incinerator-construction-notes.

12 Stauffer, Beat, SSWM Toolkit "Large and Small-scale incineration Small- Scale" GMBH, http://slideplayer.com/slide/6561462.

Generally speaking the waste types that can be disposed of by burning, without any environmental permits are restricted to vegetation, untreated wood and untreated timber. The following wastes can be burnt in a bonfire or incinerator:

- Logs and branches from fallen or chopped down trees
- Untreated timber form fence mending
- Untreated timber packaging, eg. pallets
- Hedge trimmings
- Crops and vegetation
- Leaves and bark

There should be no burning of crop residues, as this releases greenhouse gases into the atmosphere and can deprive the soil of valuable organic material. The best alternative to burning crop residue is to make compost for soil enrichment.

1.3.4. Reducing climate impact

Waste is a contributor to GHG emissions such as methane and CO_2. One key way to reduce the emission of carbon dioxide is to generate energy from waste. For example, using waste as a fuel (from spoilt produce) producing biogas from organic waste, compost made from organic waste, and rather than burning waste, ensuring that waste is recycled or reused. These help us reduce GHG.

1.4. Waste on food processing sites

FAO reports that in developing countries 40% of food loss and waste occurs during harvesting, processing and storing of produce.[13]

Food loss and waste translates into lost income for producers and higher prices for consumers. There is a need to ensure that emissions and waste streams to the environment from agriculture and food processing operations are reduced. The horticultural sector has an unprecedented opportunity to tap into alternative energy derived from harnessing waste bi-products, essentially, by capturing and reusing the high value agricultural biomass that organic waste contains once it is recovered and converted.

In fact, the reduction and conversion of waste is the new mantra for horticultural companies looking to cut costs of production both at farm and factory level. The drive for greater resource efficiency is based on the recognition that in the future we will have more scarce natural resources – it is here that prevention of waste is the ultimate goal. According to UNEP, 5 billion metric tons of biomass is generated every year from agriculture. This is equivalent to 1.2 billion tons of oil, representing 25% of current global production.

Options for reusing waste on food processing sites include:

13 FAO, "Save Food: Global Initiative on Food Loss and Waste Reduction: Key facts on food loss and waste you should know".2017. www.fao.org/save-food/resources/keyfindings/en/.

1.4.1. Mechanical treatment / shredder

Mechanical treatment of organic waste is carried out to alter the size, morphology, and/or density of the waste material. A relatively simple technology is the sizing of organic waste by shredding. The result is a product with uniform maximum dimensions, suitable for direct application as a compost or further processing. This waste option is potentially attractive in situations where transport of waste material over large distances is involved.

1.4.2. Anaerobic digestion, biogas and fuel production

Anaerobic digestion, known as AD is the biological degradation of organic material in the absence of air to produce a combustible biogas and nutrient rich organic by product (Farming Futures). The process is based on the principle of wet fermentation. This results in the production of biogas, a valuable energy carrier. The process involves the collection of organic material from agricultural waste, sewage, and the household. This is then stored in a closed, airless container that acts as the "digester".

During three to four weeks fermentation process (depending on the internal temperature of the digester), bacteria break down the feedstock, creating biogas. Biogas is a mixture of several gases and vapours, mainly methane and carbon dioxide. Because this is a slow biological process, reactors (digesters) tend to be large.

Biogas can be used directly for heat, for example, in boilers, but also converted to electricity and cleaned and pressurised to be used as a vehicle fuel. The other main output of anaerobic digestion is the digestate, an input with a high nitrogen content which can be used as fertiliser.

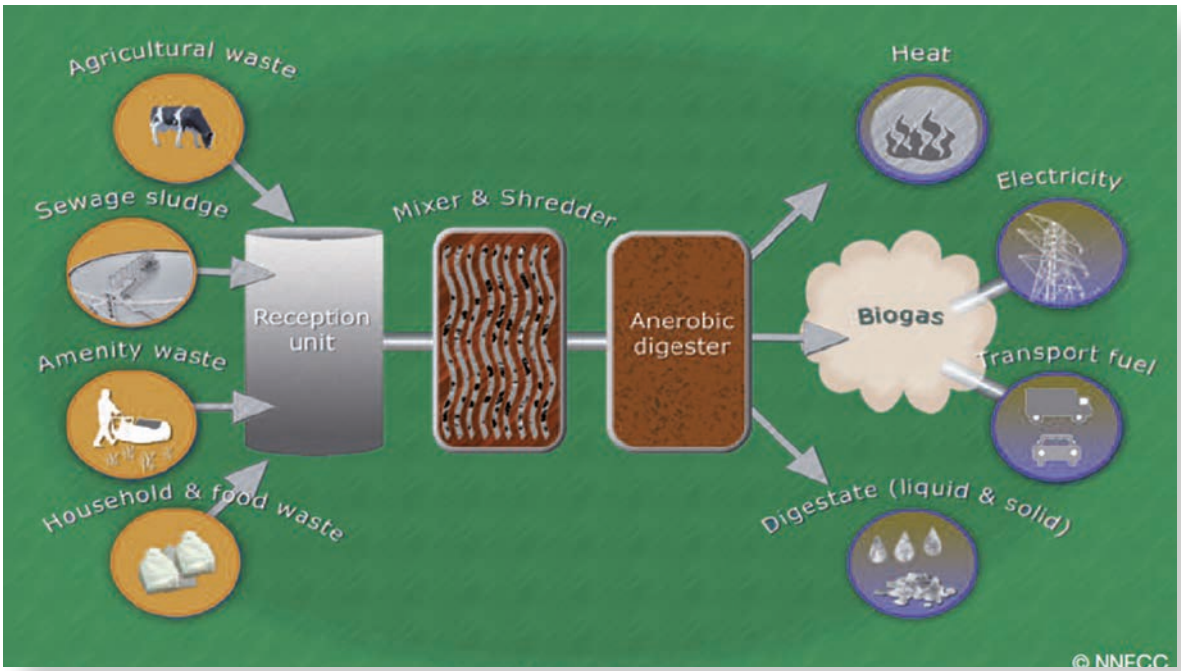


Figure 3: Anaerobic digestion
Source: FAO[14]

14 FARMING FUTURES "Focus on: farm anaerobic digestion" Fact sheet 17, 2017.

1.5. Waste in the supply chain

The FAO reports that in industrialised countries, an estimated 40% of food loss and waste happen at retail and consumer levels, often as a result of quality standards that emphasize a specific quality, size, appearance and shelf life of a product. The highest amount of food loss occurs with fruit and vegetables and roots and tuber categories.[15]

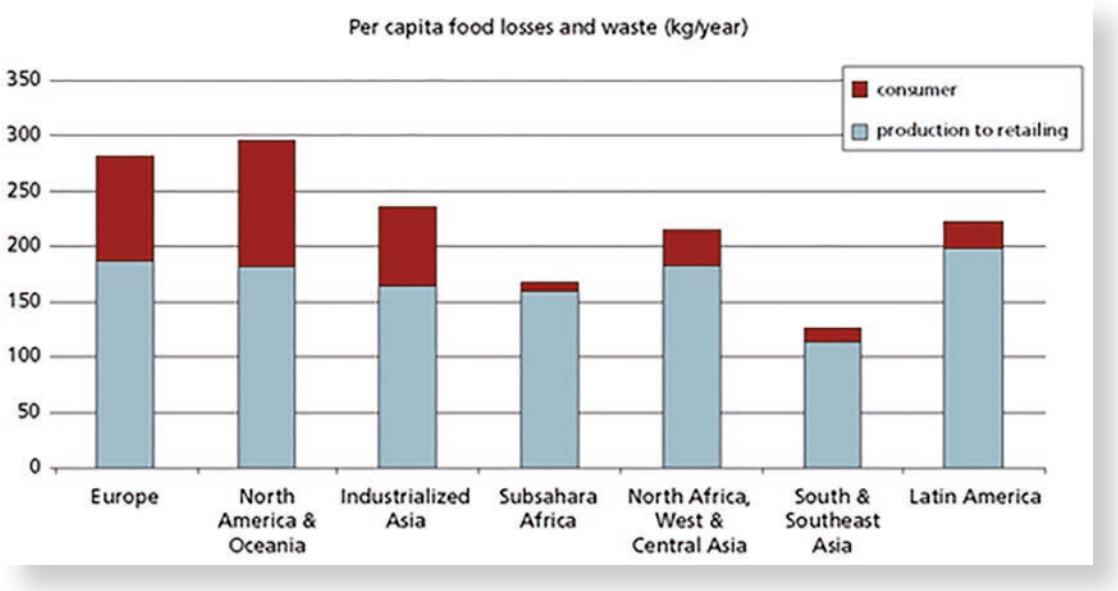


Figure 4: pertes alimentaires au niveau de la vente au détail et des consommateurs 2012
Source: FAO[16] - SAVE FOOD: Global Initiative on Food Loss and Waste Reduction

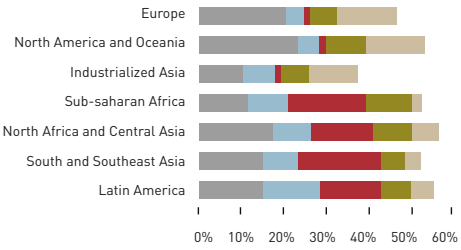
15 FAO, "Save Food: Global Initiative on Food Loss and Waste Reduction: Key facts on food loss and waste you should know". 2017. www.fao.org/save-food/resources/keyfindings/en/.

16 FAO, Infographic. www.fao.org/save-food/resources/keyfindings/en/.

45%
FRUITS & VEGETABLES FOOD LOSSES

Along with roots and tubers, fruit and vegetables have the highest wastage rates of any food products; almost half of all fruit and vegetables produced are wasted.

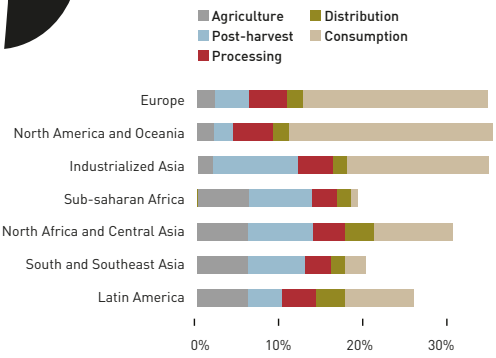
3,7 trillon apples.



30%
CEREALS FOOD LOSSES

In industrialized countries consumer throw away 286 million tonnes of cereal products.

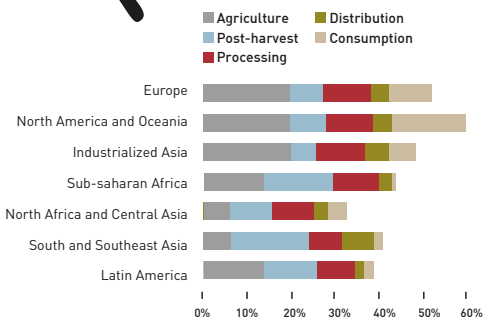
763 billion boxes of pasta.



45%
ROOTS AND TUBERS FOOD LOSSES

In North America and Oceania alone, 5 814 000 tonnes of roots and tubers are wasted at the consumption stage alone.

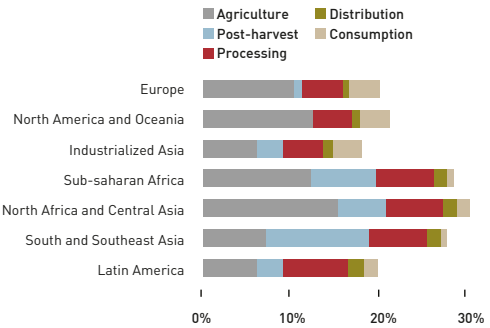
this equates to just over 1 billion bags of potatoes.



20%
OILSEAD AND PULSES FOOD LOSSES

Every year, 22% of the global production of oilseeds and pulses is lost or wasted.

This is the same as the olives needed to produce enough olive oil to fill nearly 11 000 Olympic-sized swimming pools.



The types of waste generated by consumers are different according to the level of incomes. Low and middle income countries tend to have a higher proportion of organic waste, representing up to 64% of the total waste stream. Meanwhile, populations in higher income countries tend to consume a higher rate of inorganic materials (plastic, paper and aluminium) with organic waste representing as little as 28% of the total waste stream.[17]

In order to address the current waste streams with consumers, a collaborative framework, known as the WRAP Initiative has been established to raise awareness of sustainable waste management and the use of natural resources.[18]

WRAP's mission is to accelerate the move to a sustainable, resource efficient economy by:

- Reinventing the design, production and sale of products
- Rethinking how people use and consume products, and
- Redefining what is possible, through re-use and recycling

Figure 5: WRAP Food Vision
Source: WRAP[19]

17 *Ibid.*

18 WRAP, www.wrap.org.uk.

19 WRAP "Food Vision" www.wrap.org.uk/content/food-vision.

2. THE WASTE MANAGEMENT HIERARCHY

The waste management hierarchy refers to a generally accepted management process developed in the 1970s known as **Ontario's Pollution Probe**. This hierarchy included "the three Rs" - Reduce, Reuse, Recycle – and now includes a fourth R – Recovery.[20] It recognises that no single waste management approach is suitable for managing all materials and all waste streams. The hierarchy ranks the various management strategies from the most to least environmentally friendly and encourages the minimization of GHG emissions.

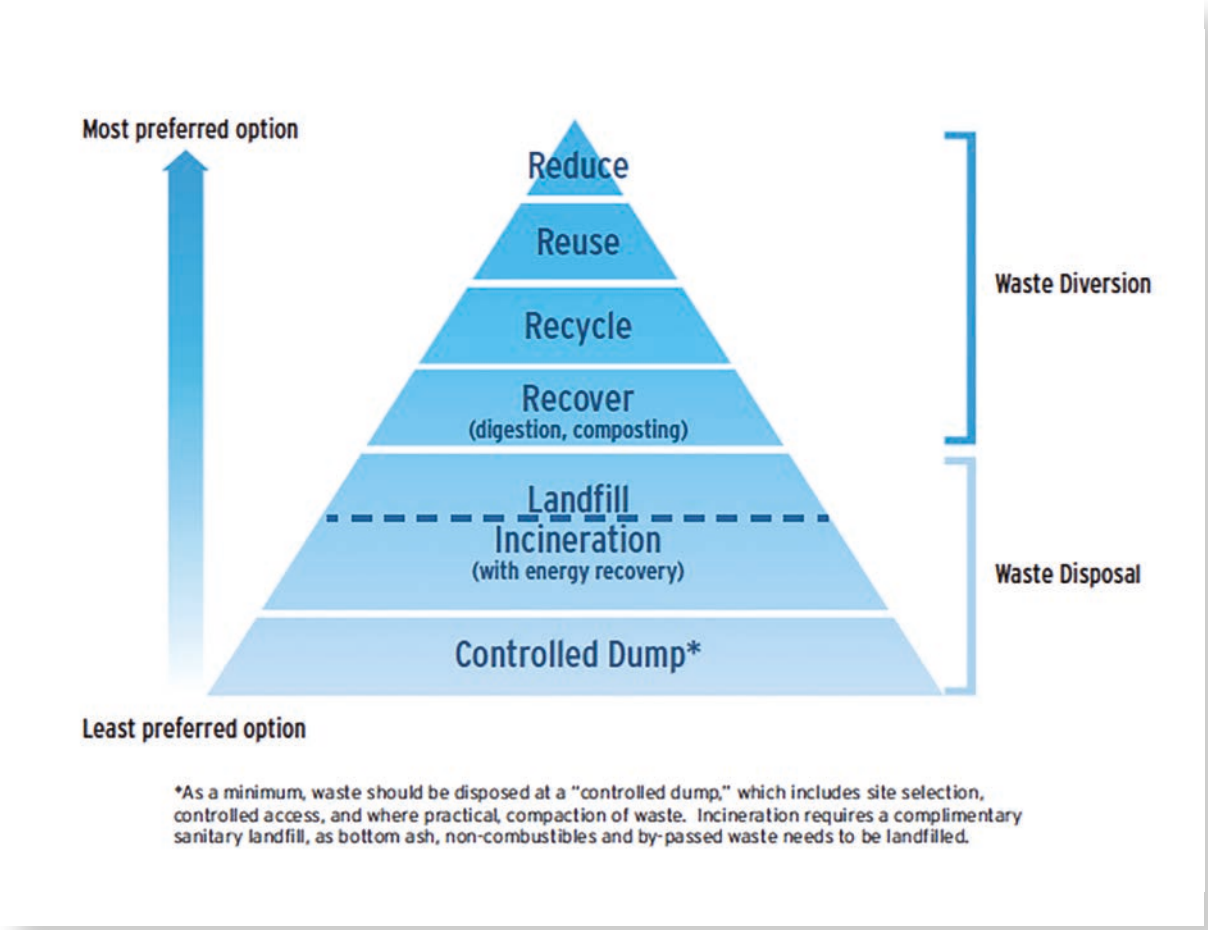


Figure 6: The Waste Hierarchy
Source: World Bank[21]

20 World Bank, "What a Waste: A Global Review of Solid Waste Management" 12 March 2012, Figure 14, Page 27- 28 www.siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

21 WRAP "Food Vision" www.wrap.org.uk/content/food-vision.

Waste management according to the hierarchy is categorised as follows:

- **Waste disposal:** A term used to describe, removing and destroying or storing damaged, used or other unwanted domestic, agricultural or industrial products and substances. Disposal includes burning, burial at landfill sites or at sea. Landfill, incineration and disposal at controlled dumps are the least preferred options.

- **Waste diversion:** or landfill diversion is the process of diverting waste from landfills. The success of landfill diversion can be measured by comparing the size of the landfill from one year to the next. If the landfill grows minimally or remains the same, the policies covering g landfill diversion are considered to be successful.

The preferred options are:

- **Reducing waste:** Also known also as waste prevention, is an approach that seeks to reduce the quantity of waste at the point where it is generated. It is the most environmentally preferred strategy and can take the form of reusing or reducing packaging and redesigning products, which allow consumers to recycle. It has two key benefits in terms of GHG emissions; firstly, it avoids emissions associated with production, and; secondly, it avoids emissions associated with methane generated from waste.

- **Reusing and recycling waste:** These are all the activities associated with collecting used, reused or unused items; sorting and processing these products into raw materials; and reusing these in new products. Essentially it involves returning these materials to the economy.

- **Recovering waste:** Through Aerobic Composting and Anaerobic Digestion. Recycling can include composting of food scraps and other organic materials. Aerobic composting (with oxygen) avoids the formation of methane associated with anaerobic composting (without oxygen) which is waste treated in an enclosed vessel and often associated with the treatment of waste water. The latter generates methane that can be flared or used to generate heat and/or electricity, also known as Energy Recovery.

- **Incineration:** Incineration of waste can reduce the volume of waste by 90%. When this process involves Energy Recovery, by converting non-recyclable waste into electricity and heat, it can generate a renewable energy source and reduces GHG emissions, by offsetting the need for energy from fossil sources and reducing methane generation from landfills. However, when incineration does not include energy recovery it can be costly and cause severe air pollution as a result of open air burning. After incineration, about 10% of waste volume remains as ash and is then sent to landfill.

- **Landfill:** Landfills are facilities created for the specific purpose of final disposal of solid waste. They cannot be built in environmentally sensitive areas and need to be engineered to protect public health and minimise environmental impact. These sites need to be controlled and monitored to check for groundwater contamination and Landfill Gas (LFG). Although energy recovery on these sites is possible from aerobic decomposition of organic matter and methane (capturing 50% of LFG), adequate landfill facilities are often lacking in developing countries. The World Bank estimates that 15-20% of the waste generated globally is collected by individuals or micro enterprises who are not registered or recognised and lead to uncontrolled dumps, which pose a risk to human health and the environment.

Lax urban waste management wreaks havoc in Africa

The deadly accident that occurred on 8 September 2016 in a landfill site for damaged products near Cotonou in Benin is a sad reminder of a sad reality. Despite some initiatives registered here and there, laxity persists in the management of urban waste in Africa. Several cities are crumbling under mountains of rubbish. Many capitals are classified among the dirtiest in the world.

Some 20 people have been killed and dozens injured. That's the toll of the explosion that devastated a landfill site for spoiled products near Cotonou, Benin.

President Patrice Talon banged his fist on the table. He promised to prosecute those responsible for this accident, which occurred in broad daylight.

"A local company came and dumped spoiled wheat flour and sprayed it with petrol before setting fire to it", a police spokesman said, and a witness described how people threw themselves on areas of the dump that were not burning to get their flour when an explosion occurred.

Source: www.francetvinfo.fr/monde/afrique/rwanda/dechets-urbains-une-gestion-laxiste-qui-fait-des-ravages-en-afrique_3062751.html.

3. NATIONAL AND INTERNATIONAL WASTE LEGISLATION

3.1. Introduction to international conventions

The current focus of legislation surrounding waste! is on the management of municipal solid waste and resource efficiency. In most countries, waste management legislation has progressed beyond simply managing municipal waste to minimise impact on human health and the environment, to a wider focus on avoiding waste, and recovering resources from waste that is generated.[22]

Three multilateral global treaties dominate global agreements around the disposal of waste. These are:

- **The London Convention 1972**, or "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter" which originally permitted dumping in the sea unless explicitly prohibited. This convention was updated with the 1996 protocol to take a more precautionary approach and subsequently prohibited the dumping of all waste at sea, unless specifically permitted.[23] The new protocol made it a requirement for countries to demonstrate that the dumping of waste would not have an environmental impact. It is important to note, that as of June 2007, countries such as the United States and the Netherlands had still not ratified the 1996 protocol.[24]

- **The Basel Convention** on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989, which was adopted in response to a public outcry following the deposits of toxic wastes in Africa imported from abroad. Between 1986 an 1988, an estimated 15 African countries were targeted by Western companies offering money for land to use as toxic waste dumps. As awareness of the environmental and social impacts grew, so did the reaction of the international community.[25] The Convention prohibits the shipment of hazardous waste to non-parties, as well as prohibiting shipments of waste to States that have specifically prohibited its import. Where the shipment is not prohibited, the Convention establishes a system of control. It is important to highlight that with the exception of Antarctica, the Convention does not prohibit any particular hazardous waste destinations. A proposed amendment to the convention, now establishes that rather than leaving it for States to decide if they do not want to import waste, the disposal of hazardous waste from developed to developing States, be prohibited altogether. Through this ban, the Basel Convention effectively moved from a system of control to a system of prevention.[26]

22 Johnson Adam, "The Development of Waste Management Law" June 2007 www.iswa.org/uploads/tx_iswaknowledgebase/538338_Paper.pdf.

23 Except a small group of wastes specifically related to activities such as fishing.

24 www.imo.org/en/OurWork/Environment/LCLP/Documents/PROTOCOLAmended2006.pdf.

25 Monzini, Paola and Massari, Monica "Dirty Businesses in Italy: A Case study of Illegal Trafficking in Hazardous Waste" Global Crime, Vol. 6, No. 3&4, August–November 2004, pp. 285–304.

26 www.basel.int.

- **The Bamako Convention** on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (1994). The convention recognized the problem of transboundary traffic in hazardous wastes and the need to promote the development of clean production methods, for the sound management of hazardous wastes produced in Africa. In particular, it called on signatories to avoid, minimize and eliminate the generation of such wastes. The convention banned dumping of hazardous wastes at sea and internal waters. As well as making it a requirement for signatory states to take preventative measures and a precautionary approach to pollution problems.[27]

- **The Rotterdam Convention on the Prior Informed Consent Procedure** for Certain Hazardous Chemicals and Pesticides in International Trade (1998 and Revised in 2015) aimed to address concerns around the dramatic growth in chemical production and trade and the potential risks posed in their import. It lays out responsibilities for their export and import with a view to protecting states, which are vulnerable due to a lack of infrastructure or monitoring capabilities. To achieve its objectives the Convention includes two key provisions, namely:

  a) **Prior Informed Consent (PIC) Procedure**, making it an obligation to disseminate the decisions of importing Parties as to whether they wish to receive future shipments of hazardous chamicals, and

  b) **Information Exchange** facilitating information exchange for a very broad range of potentially hazardous chemicals. Together, these instruments aim to ensure that governments have the necessary information to enable them to assess the risks of hazardous chemicals and to take informed decisions on their future import.[28]

- **The Stockholm Convention 2001 on Persistent Organic Pollutants** is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically and have harmful impacts on human health or on the environment. The Convention requires its parties to take measures to eliminate or reduce the release of POPs into the environment. Article 6 in particular addresses stockpiles and wastes consisting of, containing or contaminated with POPs, establishing that these must be managed safely and in an environmentally sound manner. The Convention also requires that wastes containing POPs are transported across international boundaries taking into account relevant international rules, standards and guidelines.[29]

27 www.opcw.org/chemical-weapons-convention/related-international-agreements/toxic-chemicals-and-the-environment/bamako-convention/.

28 www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx.

29 The Stockholm Convention, http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx.

- **Industry standards such as GLOBALG.A.P.,** whilst not embedded within international legislation, are a widely implemented set of standards in which also address the treatment of waste in the horticulture sector. In summary key elements of waste management on farm include:

  1. Collecting, classifying and recycling as much waste as possible;

  2. Reusing as much waste as possible (composting organic waste);

  3. Safely disposing of empty containers;

  1. Working to reduce greenhouse gases;

  4. Raising awareness on farm about processes and safe waste management.

3.2. Legislation around safe disposal and recycling

National legislation on waste management will fall under the remit of local governments and will vary from one country to another. This said, most countries and cities around the world are being encouraged to adopt **Integrated Waste Management** Plans (IWMP) that cover systematic issues around the collection, transport, recovery and disposal of waste. These are increasingly being embedded into national legislative frameworks and developed in consultation with stakeholders from local authorities, NGOs, private sector, informal sector and service users.

According to the Dutch NGO WASTE, national legislation on waste management should follow principles of:

- 'Equity' for all citizens to access to waste management systems;
- 'Effectiveness' of the system to safely remove waste;
- 'Efficiency' to maximize benefits and minimize costs; and,
- 'Sustainability' from an environmental, social, economic and institutional perspective.[30]

30 Dutch NGO WASTE.

The UN Habitat Framework also identifies **three key system elements** that have to be addressed through legal frameworks to ensure integrated waste management:[31]

1. **Ensuring public health:** This is a key concern and driver for most legislation given that waste management is essential to maintaining public health. Research suggests that were solid waste is not properly collected this can lead to cholera and there are "significantly higher rates of diarrhoea and acute respiratory infections for children living in households where solid waste is dumped or burned in the vicinity".[32] Uncollected waste also blocks drains and causes flooding and subsequent spread of water-borne diseases. Relevant legislation can include:

    - Landfill directives, introducing technical requirements for waste destined for landfills and setting targets for the reduction of biodegradable waste;
    - Hazardous waste regulations;
    - Waste regulations concerning toxic gases resulting from burning waste;
    - Waste transport and shipment regulations;
    - Regulations concerning toxic gases resulting from burning waste.

2. **Ensuring environmental protection:** The driver to improve waste disposal and/or develop engineered landfills has been one of public health and environmental protection. An important risk that comes from dumping in unregulated sites. Environmental threats include contamination of groundwater and surface water by leachate. In a number of developing countries, there have also been major accidents involving landslides on unstable waste slopes at uncontrolled solid waste sites. Relevant legislation can include:

    - Environmental permits for the recovery and disposal of waste, ensuring that operations are registered with the authorities;
    - Handling electrical and electronic equipment waste;
    - Batteries directives.

31 Waste and Resource Management, Volume 116, Issue WR2 "Integrated Sustainable Waste Management in developing countries" http://eprints.whiterose.ac.uk/78792/13/Wilson%20et%20al.1.pdf.

32 World Bank, "What a Waste: A Global Review of Solid Waste Management" 12 March 2012, www.siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

3. **Ensuring efficient resource management:** the global market for recyclables is increasing and this provides an opportunity for saving energy and costs. For example, the market for consumer scrap metal is estimated at 400 million tonnes annually.[33] However, governments in developing countries still depend on public funding mechanisms and income raised through taxation to safely manage and dispose of waste. Some cities in low-income countries (e.g. Bamako, Mali) have delayed construction of an engineered landfill partly due to the unresolved problem of financing for transport and operation (Keita et al., 2010).

The difficulty for many developing countries to fund effective waste management programmes creates a dependency on informal and unregulated sector to deliver waste management and recycling services.

Relevant legislation can include i) National Recycling strategies and ii) Packaging, packaging waste and packaging regulations.

33 World Bank "Waste Not, Want Not – Solid Waste at the Heart of Sustainable Development" 3 March, 2016.

3.3. National Integrated Solid Waste Management (ISWM) Plans

The recovery and disposal of waste will generally require permits under local legislation with the aim of preventing harm to human health and the environment. Countries and cities around the world are encouraged to develop what are officially termed as **Integrated Solid Waste Management Plans** (ISWM) which establish a clear framework for dealing with waste.

In theory, ISWM should include:[34]

- National policies with clear aims, objectives and initiatives related to waste management;
- Specific scales for national, regional or local plans, in line with the distribution of the population;
- Data on waste generation, including projections for the waste plan (usually over 15-25 year timeframes);
- Identification of proposed options for waste collection, transport, treatment and disposal of types and quantities of waste; covering financial aspects, technical aspects, governance, measurement and monitoring of plans;
- Evaluation of the most environmentally friendly options for safe disposal of waste, integrating technical, environmental, social and financial resources;
- Associated institutional reforms and regulatory arrangements needed to support the plan;
- Specification on the proposed monitoring and controls that will be implemented and their reporting frameworks;
- Financial assessment of plans, including costs of investment into facilities and services, over the lifetime of the plan;
- Sources of revenues such as taxation that can be realistically applied including subsidies and user fees;
- The requirements for managing all non Management of Solid Waste arising, facilities required and related service providers, as well as allocation of costs;
- Outline of consultation processes with interested stakeholders, including local authorities and business institutions;
- A long term (5-10 years) and short term (1-3 years) implementation plan;

34 World Bank, "What a Waste: A Global Review of Solid Waste Management" 12 March 2012, Page 25 www.siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

- An outline of key management facilities eg. landfills, compost plants and transfer stations;

- An assessment of GHG emissions and the role of ISWM.

Generally speaking, with hazardous waste, strict controls will have to apply from the point of its production, its movement, management and recovery.

3.4. Case study: Rwanda's Integrated Solid Waste Management Plan[35]

Rwanda is facing significant challenges in relation to solid waste management. Waste generation is increasing, while a sizeable portion of it is disposed on improperly located and operated dumpsites, resulting in adverse impacts on environment and health. The country has a backlog in waste legislation enforcement as well as in coordination and promotion of existing efforts to recycle and dispose waste properly.

The objective of Rwanda's Integrated Solid Waste Management Plan (ISWM) is to manage the safe disposal of waste, to protect human health and the environment.

A National Task Force has been established to ensure an affordable, integrated approach to solid waste management based on the international waste hierarchy of:

- Reducing the amount and toxicity of material entering the waste flow (minimization);
- Reusing as much material as practicable;
- Recycling the waste that cannot be used and recovery of resources;
- Residue disposed of in an environmentally sound way.

This approach aims to mobilize all public and private stakeholders and consider the relevant financial, technical, cultural, organizational and legal aspects. A clear division of responsibilities in terms of regulating, monitoring, promoting and operating functions has been established among public entities at national and district level as well as among private business, communities and households.

The ISWM aims to ensure full cost recovery and to encourage private and community initiatives for financing and operating waste management operations.

The existing legislation and regulatory framework has been updated and has established minimum levels of service and environmental protection. Such levels can be scaled up over time, but are required to remain realistic i.e. technically, socially and economically enforceable at each stage of development. Enforcement is to be accompanied by user-friendly advice and guidance and addresses aspects such as operating licenses, producer responsibilities, landfill regulation, tariffs, and disposal of hazardous, industrial and agricultural waste, illegal dumping, prosecution and recovery of clean-up costs.

35 www.mininfra.gov.rw/index.php?id=90.

The following components have been developed taking into account the waste hierarchy:

- **Waste reduction, prevention and minimization:** Waste prevention is at the top of the waste hierarchy and number one priority for the integrated approach to solid waste management.
- **Recycling**: Recycling can reduce waste to landfill but also provide economic, environmental and social positives. The State shall assist private sector and community initiatives in establishing markets for recyclable products with priority for materials which are currently being recycled and/or can find sustained market demand. Such support may include training and the provision of reimbursable funding or grants.
- **Recovery**: At the dumpsite, organic garden waste and paper are the source of most of the damaging leachate, greenhouse gases and odours. But they also represent a valuable resource which should be recovered, e.g. composted or transformed into briquettes.
- **Collection**: Due to high transportation costs, collection efficiency is crucial and shall be optimized. Private and community initiatives for solid waste collection are to be encouraged also outside Kigali in secondary urban centres.
- **Landfill:** Uncontrolled dumpsites shall cease to operate and be replaced with environmentally sound landfills. Identification of future landfill sites and technologies shall be undertaken based on selection processes considering technical, financial, social and operational criteria.
- **Hazardous waste**: Due to the elevated and often concentrated environmental risks, a map and register of hazardous industrial and medical waste producers and products shall be established and include actual techniques and equipment used for disposal. To comply with environmental legislation, guidelines are to be edited for safe waste handling, storage, transport, treatment and drop-off or disposal for each category of hazardous waste.

3.5. Challenges around the safe disposal of waste

Waste management has become a priority issue globally. The rising rates of consumption, coupled with rising population have resulted in the generation of waste beyond the handling capacities of local waste management authorities. Safe handling and disposal of high volumes of waste also carries high handling costs. Whilst great efforts have been on-going to reduce, recover, recycle and reuse waste, the 1980s saw the emergence of the hazardous waste trade between developed and developing countries. The reasons were mainly financial, given that the

average disposal cost for one tonne of hazardous waste in a Western country (with safe and legal benchmarks) was between US$100 and US$2,000, whilst in Africa the cost was between US$2.50 and US$50.[36]

Research suggests that during the 1980s, of the 300 million tonnes produced each year in the developed world, some 50 million tons were shipped to Africa. This trade was driven by a growing demand for clandestine and cheaper services in the sector, low business ethics, delays in implementing proper waste-management policies and legislation, and generally low public awareness regarding the threat posed by eco-crimes.[37]

Despite the existence of international agreements to protect illegal trafficking and dumping of waste, the problem continues. The illegal trade of waste has become big business for organised crime.

In 2009 there were reports of a series of raids across recycling sites in the UK to enforce the EUs Waste Electrical and Electronic Equipment (WEEE) directive, which focuses on safe disposal of computers, monitors, fridges and assorted electrical waste and makes it a legal requirement that components be broken down in the countries generating the waste. Although there are clear regulations in countries across the EU and the US about safe recycling in home countries, experts estimate that between 50% and 80% of all material collected in the US and significant amounts of waste collected in Europe is exported abroad to Africa, Latin America, China and India.[38]

The impact of waste on the health and the environment is well documented. People are poisoned as a result of exposure to harmful chemicals and substances, the spread of infections diseases and the contamination of land and waterways leads to diaorrhea, denghe fever and cholera.

Key impacts result from:[39]

- The disposal of industrial hazardous waste with municipal waste, which exposes people to chemical and radioactive hazards. In particular, through the release of untreated chemicals such as cyanides, mercury, and polychlorinated biphenyls. These are highly toxic and exposure can lead to disease or death. There are documented cases of cancer in residents exposed to hazardous waste.

- Coloured plastics are harmful as their pigment contains heavy metals that are highly toxic. Some of the harmful metals found in plastics are copper, lead, chromium, cobalt, selenium, and cadmium. In most industrialized countries, colour plastics have been legally banned.

36 Monzini, Paola and Massari, Monica "Dirty Businesses in Italy: A Case study of Illegal Trafficking in Hazardous Waste" Global Crime, Vol. 6, No. 3&4, August–November 2004, pp. 285–304.

37 *Ibid.*

38 P. Warren, "Organised crime targets waste recycling", *The Guardian*, 8 July 2009.

39 Health Impacts of Solid Waste http://edugreen.teri.res.in/explore/solwaste/health.htm.

- Uncollected solid waste can also obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground of disease. These have been linked to outbreaks of choleara, denghe fever and diaorrhea.

- Waste dumped near a water source also causes contamination of the water body or the ground water source. Direct dumping of untreated waste in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain through the plants and animals that feed on it.

3.6. Case study: Dumping of waste in Ivory Coast[40]

In 2006 the Ivory Coast was involved in a huge toxic waste dump which caused a health crisis in Abidjan. The case involved a ship, the Probo Koala, chartered by the multinational oil and commodity shipping company Trafigura which offloaded toxic waste to an Ivorian waste handling company which then disposed of it at the port of Abidjan. Late at night on the 19th of August 2006, 12 trucks drove away from the port at Abidjan, Ivory Coast. During the night and early morning the hazardous materials were dumped at 18 different sites around the city, close to densely populated areas. People near the dump sites immediately began to feel the toxic effects of the waste.

Trafigura originally planned to dispose of the waste - 500 tonnes of fuel, caustic soda, and hydrogen sulfide – at the port of Amsterdam in the Netherlands. The company refused to pay Amsterdam Port Services (APS) for disposal after they raised the charge from €27 to €1,000 per cubic meter. The Probo Koala was reportedly turned away by several countries before offloading the toxic waste at the Port of Abidjan. It is estimated that 15 people died as a result of this environmental crime, while 108,000 individuals sought medical assistance. Today residents in Abidjan continue to suffer from medical conditions associated with toxic poisoning.

40 Toxic Waste Dumping in Abidjan 2006 www.statecrime.org/testimonyproject/ivorycoast.

In 2008, a civil lawsuit in London was launched by almost 30,000 Ivorians against Trafigura. On 23 July 2010, Trafigura were fined €1 million for the transit of the waste through Amsterdam before being taken to the Côte d'Ivoire to be dumped. While previous settlements have been made in the case this is the first time Trafigura have been found guilty under criminal charges over the incident. In 2012 Trafigura and the Dutch authorities agreed to a settlement, obliging Trafigura to pay a 1 million euro fine and payment to the Dutch authorities of a further 300,000 euros in compensation. To this day, Trafigura denies responsibility for the toxic waste dumping and maintains that it believed the local company it hired in Abidjan to dispose of the waste would do so safely and lawfully.

Photo: The ship Probo Koala
Source: International Statecrime Initiative[41]

3.7. Public Private Partnerships: Sector Based Programmes and Approaches to Waste Management and Recycling

The horticultural sector has an unprecedented opportunity to tap into alternative energy derived from harnessing waste bi-products. Essentially, by capturing and reusing the high value agricultural biomass that organic waste contains once it is recovered and converted. The drive for greater resource efficiency is based on the recognition that in the future, we will have more scarce natural resources – it is here that prevention of waste is the ultimate goal.

Waste management and recycling are seen as key drivers of sustainable development. Key institutions which are currently developing industry and sector wide approaches to sustainable waste management include:

41 WRAP "Food Vision" www.wrap.org.uk/content/food-vision.

- *The International Solid Waste Management Association (ISWA)*[42]

Is responsible for running the Global Partnership on Waste Management at UNEP. The organisation develops international workplans on waste and climate change and aims to promote a holistic approach to waste management that will impact on GHG emisions from energy, forestry, agriculture, mining, transport and manufacturing.

- *UNEP's Division of Technology, Industry and Economics -International Environmental Technology Centre (DTIE IETC)*[43]

The organisation focuses on the promotion and enhanced use of waste agricultural biomass through awareness raising and capacity building programmes. The aim is to promote industrial and commercial use of waste agricultural biomass by demonstrating appropriate technologies, assisting local governments to develop policies and facilitating partnerships.

DTIE IETC also runs the work plan for Integrated Solid Waste Management (ISWM) and is helping countries to redesign waste generation systems to effectively deal with diversified waste streams. The aim is to enable local governments to reduce the overall amount of waste generated and to recover materials for recycling and for the generation of energy, with an aim to raising revenue from these activities and offsetting the expenditures associated with effective waste management systems.

- *UNEP's Division of Technology, Industry and Economics – Responsible Industry and Value Chain Unit (DTIE – RIVU)*[44]

This department focuses on waste minimisation strategies from production to consumption areas. On the production side, the focus is on optimising resource and energy use lowering toxicity levels during manufacture, for example, through improved product design, cleaner production and reuse of scrap material. On the consumption side, the organisation aims to increase consumer awareness and responsibility around the environmental impact of consumption patterns. RIVU provides support by promoting best practices for waste minimisation, providing training materials and building capacity at national and local level in pilot cities and countries.

- *The Africa Institute*[45]

This is the Basel and Stockholm Convention Regional Centre for English speaking African countries which provides training, capacity building and information on environmental sound waste and chemical management, including hazardous wastes. It also oversees collaborative frameworks from many African countries that are signatories to Multilateral Environmental Agreements and aims to foster sound use of chemicals. Legislation that bans the release of hazardous waste into the environment

42 www.iswa.org.

43 www.unep.or.jp/ietc/SPC/publications.asp.

44 www.unep.org/resourceefficiency/what-we-do/responsible-industry.

45 http://africainstitute.info.

is often in place but governments often lack technical equipment and human resource to enforce it.

• *Food Agriculture and Natural Resources (FAO)*[46]

In 2014 the organization launched "The Save Food Initiative" a global partnership of public and private sector organisations and companies working to promote waste reduction programmes and specifically food loss.

The programme is promoting best practice on successful campaigns which have achieved a reduction in food loss.

It has **four key pillars of action**:

1. Awareness raising on the impact of, and solutions for food loss and waste.

2. Collaboration and coordination of world-wide initiatives on food loss and waste reduction.

3. Policy, strategy and programme development for food loss and waste reduction.

4. Support to investment programmes and projects, focusing on training of food industry and organizations specializing in waste reduction.

• *The World Bank*[47]

The World Bank is currently providing loans and technical assistance for infrastructure around waste management. The bulk of these projects are designed to reduce the climate change impacts of waste management through carbon capture and carbon finance. The aim is to use carbon funding streams to cover the costs of waste management programmes. The bank currently has over 150 projects with waste management companies, to the value of US$3.5 billion and is developing a methodology for methane avoidance through recycling.

46 www.fao.org/save-food/en/.

47 www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

4. IMPACTS ON SOIL, WATER, AIR, HEALTH AND THE LIVING ENVIRONMENT OF AGRI-FOOD SECTOR WASTE

4.1. Nature of waste and their impacts

The types of waste generated from food supply chains vary widely, from biodegradeable vegetable waste, to non-biodegradeable plastics, to toxic phytosanitary products. As a result, the impacts which of improper waste management are vast and negative effects may occur in locations quite remote from where the waste was disposed of.

The following table lists the types of impacts caused by improper horticultural waste management. Of course the magnitude of these impacts will increase if waste is left over longer periods and if the volume of waste builds up over time. For methods of waste reduction, see Chapter 3.

	Waste Type	Impacts
1.	**Phytosanitary products and fertilizers** Obsolete stock, excess mixture, empty packaging and containers etc.	**Soil** – Soil ecology – the makeup which ultimately determines how rich and productive the soil is for growing crops – can be dramatically altered by pollution from plant chemicals. **Water** – Groundwater can become contaminated from the products themselves, or from decaying packaging. This can have toxic effects on the people and biodiversity which rely on this water for drinking. Effects can also pass along the food chain; fish swimming in a river polluted with chemical products can pass on their toxicity to humans if eaten. **Air** – Incinerating packaging can release toxic substances such as dioxins, which cause air pollution and may contribute to acid rain. The ash may contain heavy metals and other toxins **Biodiversity** – The negative effects of chemical waste can be passed along food chains, causing "biomagnification" – this is where the impacts are multiplied at each level of the food chain, ultimately causing very significant changes to local biodiversity. Insect pollinators such as bees and butterflies may be reduced in number, resulting in lower levels of pollination and therefore reduced crop yields. **Human health** – Toxic substances can enter the human body through any of the above pathways, causing all manner of impacts including respiratory problems, cancers, hormone disruption and disruption of the nervous system.

	Waste Type	Impacts
2	**Waste linked to engines** Batteries, oil etc.	**Biodiversity and human health** – Batteries contain toxic and corrosive acids that can cause poisoning and burns to people and animals. Engine oil can have toxic effects on biodiversity. For example, oil leaching into vegetation on the ground or in water can kill or contaminate fish. **Soil** – Oil leaching from badly-maintained machinery will be washed into the soil when it rains. This can affect the soil ecology such as its water holding capacity and biological composition, and therefore also crop yields. **Water** – When oil and corrosive substances leach into the soil, they can end up contaminating groundwater sources which people and animals drink from. This can have serious short- and long-term health effects.
3	**Organic matter**	**Human health** – Improper disposal of organic waste attracts pests such as flies and rats, which spread infectious disease through contaminating human food and through bites. Further, when organic matter is left in piles, pools of stagnant water which are left following rainfall can be a breeding ground for disease-carrying mosquitoes. **Natural environment** - Decaying organic matter can leach into watercourses, causing a build up of algae that deplete oxygen levels in the water, thereby killing fish and other aquatic organisms. The decay of organic matter can also cause bad smells which are intensified in hot weather, making areas uninhabitable for people.
4	**Waste linked to irrigation system and other sundry items**	**Biodiversity** – equipment such as tubing and pipes from irrigation systems, plastic seedling trays and bags, containers, films for mulch and bale wrapping may be harmful to animals which may try to eat them. **Human health** – when waste plastic, rubber and other non-biodegradeable materials are burned, toxic chemicals pollute the air and can severely damage human health such as lung damage, cancers, hormone disruption. Further, toxic smoke can be carried in the air over long distances, affecting people and places far wider than the original source of pollution.
5	**Energy waste**	**Natural environment** – Gasoline and diesel fuel contain hazardous substances such as benzene that can be harmful even in small amounts, and it takes very little gasoline to contaminate water. The impacts on biodiversity are also extremely negative. When fuels spill onto soil, or leach into the soil following rainfall, the negative effects on soil ecology result in lower germination of crops and therefore reduced yields for the farmer.

	Waste Type	Impacts
6	**Waste and its impact on biodiversity**	**Breakdown of non organic waste** – Many of the materials disposed of as general waste can last in the environment anywhere from hundreds to thousands of years. **Plastic waste** – Lightweight materials like plastic bags and film can easily be dispersed from rubbish bins and landfill. Much of this lightweight material presents a range of hazards for wildlife and domestic animals who can become entangled or choke if they accidentally mistake litter for food. The chemical composition of plastic means that it takes a substantial period of time to break down in the environment, and is capable of travelling long distances without decomposing. Around 80% of plastic litter found in the ocean has travelled there from inland waterways. **Pollution** – If a landfill site is not properly sealed, a toxic pollutant known as leachate can escape into the surrounding groundwater causing environmental problems for plants and animals living downstream.

4.2. Produce classification: fit for sale, or not fit for sale?

All too often, produce is rejected by a customer due to it not meeting their strict requirements on uniformity in appearance, size, ripeness and flavour; when produce is not graded strictly, it runs the risk of not meeting the required standards. The most commonly known standards are the EU Marketing Standards for Fresh Horticultural Produce.[48]

These standards are designed to help promote fair competition throughout the marketing chain. They provide a framework for quality, grading and labelling which allows produce to be bought without being seen.

For the grower, the standards are established to make sure that produce is traded fairly, with a consistent and detailed system of quality, grading and labelling. They help to improve the returns to growers for good quality produce, by preventing unfair competition from poor quality produce, or produce falsely claimed to be of a higher quality than it is.

48 www.gov.uk/guidance/comply-with-marketing-standards-for-fresh-fruit-and-vegetables.

There are 2 main standards:

• *The Specific Marketing Standard (SMS)*

The EU marketing standards apply to most fresh horticultural produce. Almost all fresh products must meet the general marketing standard (below), but the following important products are covered by the more particular specific marketing standard:

- Apples
- Citrus fruit (including oranges, soft citrus and lemons)
- Kiwi fruit
- Lettuces (including curled and broadleaved endives)
- Peaches and nectarines
- Pears
- Strawberries
- Sweet peppers
- Table grapes
- Tomatoes

• *General Marketing Standard (GMS)*

The applies to most other fresh fruit, vegetables, nuts and herbs

Although these standards exist to allow fair competition and to facilitate international trade, there are often cases where food is rejected because it does not meet strict buyer criteria or the necessary standard.

As a result, horticultural produce frequently ends up as waste with the farmer receiving no financial compensation. Farmers will therefore be better-placed if several markets for their produce are sought; produce can then be sorted and graded into different classes, with the best grade reaching a higher price and lower grades still bringing in revenue for the farmer, whilst also minimising waste.

Sorting and grading should therefore be seen as an essential post-harvest step. Most commonly, size is the basis on which fruits and vegetables are graded.

4.3. The promotion of 'ugly food' or 'wonky vegetables' to address food waste

There is wide consensus from the food industry, that the strict application of standards and the onus on appearance often leads consumers to reject food that is safe for consumption. In an attempt to decrease the amount of food being wasted, several awareness raising campaigns with retailers are underway to promote the use of 'ugly' food which is safe for human consumption. Walmart, Tesco and Carrefour, have spearheaded campaigns on 'wonky vegetables'.[49]

The aim of the 'ugly food' campaigns currently being implemented by retailers in the EU and the US is to encourage consumers to consume products that may not appear strict appearance or size criteria, but are otherwise perfectly safe for human consumption. This campaign also aims to decrease the need for packaging and extend shelf life of food products.

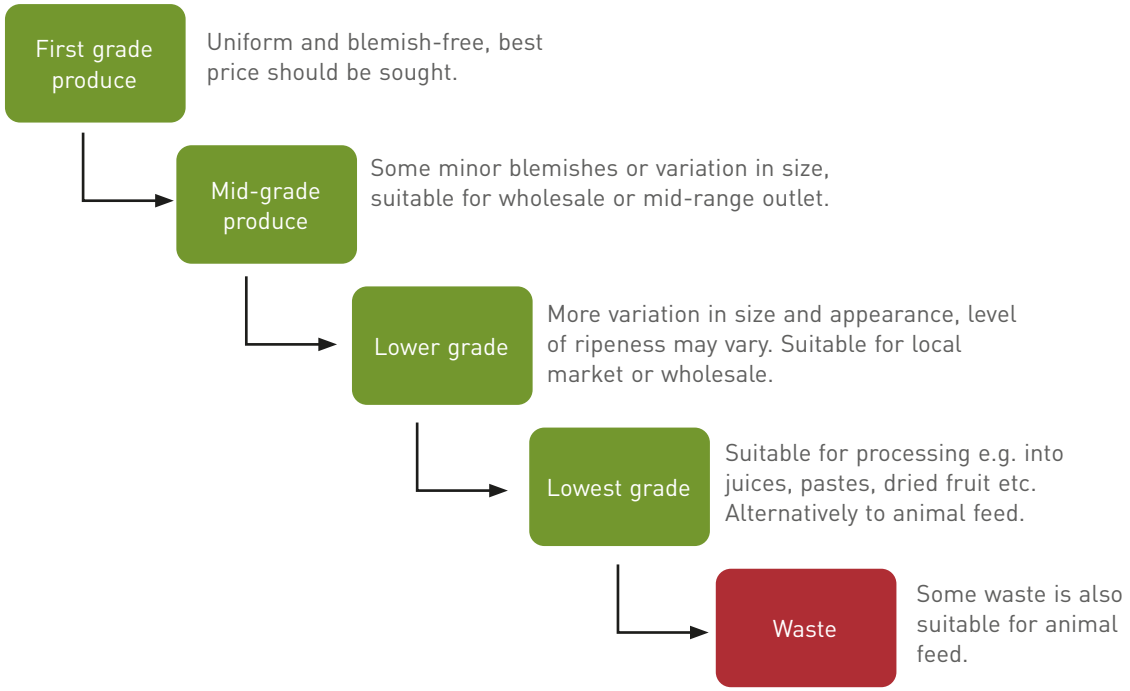


Figure 7: Example of grading produce for a range of potential markets

49 www.wonkyvegboxes.co.uk/about.

5. THE CIRCULAR ECONOMY

5.1. What is circular economy ?

In recent years, the global market for recyclables has become significant. The World Bank estimates that post consumer scrap metal is equivalent to 400 million tonnes and for paper and cardboard it is 175 million tonnes. If recuperated, this represents a global value of almost $30 billion per year. Producing new products with secondary materials can also save energy. One example is producing aluminium from recycled aluminium, which requires 95% less energy.[50]

Turning waste into a resource is one key to a circular economy. The objectives and targets set in European legislation have been key drivers to improve waste management, stimulate innovation in recycling, limit the use of landfilling, and create incentives to change consumer behaviour. The basic concept of the circular economy is that by re-manufacturing, reusing and recycling waste, one industry›s waste becomes another›s raw material. This is ultimately the most sustainable model, eliminating waste and ensuring the efficient use of resources throughout the lifecycle of the product.

WRAP describes the circular economy as "an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life" as illustrated in the diagram below.[51]

50 World Bank, "What a Waste: A Global Review of Solid Waste Management" 12 March 2012, Page 27 www.siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

51 WRAP, The Circular Economy www.wrap.org.uk/about-us/about/wrap-and-circular-economy.

Figure 8: The Circular Economy
Source: WRAP

The Ellen McArthur Foundation claims that within this context, manufacturers and retailers could eventually retain ownership of their products and act as service providers. Within this system, companies would sell the use of the products, rather than the products themselves. "Such a system would require changes in product design and business models to generate more durable products that can be disassembled, remanufactured or refurbished".[52]

5.2. The circular economy and horticulture

Within a horticultural context, the circular economy system is restorative by design; it focuses on the use of renewable energy; minimises, monitors and where possible eliminates the use of toxic chemicals; and eradicates waste through careful design at the point where waste is generated.

In December 2015 the EU Commission adopted a Circular Economy Action Plan[53] which created the momentum for companies and governments to rethink the approach to food production, consumption and waste management.

The package included legislative proposals on waste, as well as long term targets to reduce landfill and increase recycling and reuse. The plan attempts to close the loop of product lifecycle and proposes a series of actions from production to consumption,

52 Ellen McArthur Foundation, "The Circular Economy and Modern Agriculture", www.ellenmacarthurfoundation.org/assets/downloads/Schools-Colleges-WLL-Lesson-Plan-5-F.pdf.

53 EUROPEAN COMMISION "Closing the loop - An EU action plan for the Circular Economy" http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614.

repair and manufacturing, waste management and secondary raw materials that would be fed back into the economy.

It is possible that in the future, products destined to the EU markets will need to meet requirements around food waste, eco-design, organic fertilisers and guarantees for consumers. This is in line with EU commitments on sustainability and in particular to the Sustainable Development Goal 12 on Sustainable Consumption and Production Patterns. The most salient points of the EU Circular Economy Action Plan relating to food are highlighted in the following initiatives:[54]

- Food Waste: The EU recognizes this is a key area in the circular economy, which needs to be tackled at various levels in the food value chain. In 2016, the EU launched a multi-stakeholder platform on Food waste prevention, the aim of which was to develop an EU methodology to measure food waste, facilitate food donation and use former foodstuff as feed. The EU Platform on Food Losses and Food Waste, will aim to meet Sustainable Development Goal commitment to halve food waste per capita by 2030.

  The EU is also reviewing regulations applying to food redistribution, to remove barriers to both donors and receivers, for the redistribution of safe, surplus food in the EU. Finally, the EU is developing guidelines on the use of former foodstuff to be used in animal feed with the aim of reducing food waste, avoiding burning or landfills and substituting cereals and oil seed in animal diets, whilst reducing EU dependence on feed imports.

- Ecodesign: The EU recognises that the possibility to repair or recycle a product and reuse its components and materials is dependent on the initial design of the product. Measures to date, have focused primarily on energy efficiency. However, efforts are underway to explore potential for durability, reparability, upgradeability, design for disassembly, ease of reuse and recycling.

- Review of Waste-to-Energy processes: The EU is currently developing guidelines for the recovery of energy from waste and the role of various processes in line with the waste hierarchy.

- Water Reuse: Under the Common Implementation Strategy for the Water Framework Directive the EU aims to better integrate water reuse in water planning and management. In particular the reuse of treated wastewater in safe and cost effective conditions to increase water supply and alleviate pressure on resources. Facilitating water reuse for irrigation in agriculture will also contribute to recycling of nutrients by substitution of solid fertilisers.

54 EUROPEAN COMMISSION "Report from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions on the implementation of the Circular Economy Action Plan" Brussels, 26.1.2017.

- Legislative proposal on fertilisers: The EU has proposed regulations to create a single market for fertilisers made from secondary raw materials (in particular recovered nutrients). The aim is to make the fertilizer sector less dependent on the import of primary raw materials such as phosphate and to recover these from organic waste. The EU will incentivize the use of organic waste and by products, to be used in CE marked fertilizing products by allowing their unrestricted access to the single market, including for organic fertilizing products.

- Launch of Innovation Deals: The EU aims to remove legislative barriers to the circular economy by piloting "Innovation Deals" in water, waste and energy sectors. One such deal is focusing on regulatory obstacles to sustainable waste water treatment using anaerobic technology.

- Legislative proposal on the sale of online goods: The proposal lengthens consumer protection against defective products sold online from six months to two years. The aim is to contribute to durability and repairability of products and prevent these being thrown away. The legislation is designed to incentive the production of higher quality more durable products. Additionally, the proposal extends this protection through an equal two year guarantee for second hand goods, in order to promote second hand goods.

- Integration of Circular Economy in permits for industrial installations: Certain aspects of the circular economy have been integrated into Best Available Techniques Reference Documents (BREFs) for new industrial installations with the aim of reducing waste generation, boosting recycling and reducing resource use for indsutries coveed by he Industrial Emissions Directive. Examples can be:

  - Techniques to save natural resources, by improving use of secondary raw materials, increase enegy efficiency and reduce waste water generation
  - Techniques to reduce waste generation through alternative usese of process residues.

- Action on Environmental Claims: Through its Unfair Commercial Practices Directive, the EU aims to make green claims more transparent. The guidance addresses greenwashing of companies making false, unclear, unintelligible or ambiguous statements towards consumers. The aim is to increase consumer confidence and trust in company labels and initiatives around the circular economy.

5.3. Case study: Growing sugar in Brazil: Developing a restorative and regenerative approach to farming[55]

The Balbo Group is made up of three sugar mills in Brazil. In 2010 the company decided to switch 20,000 hectares of sugar cane plantation from conventional technology of production into a revitilising agricultural system. The results were extremely positive, with the company becoming the largest producer of organic sugar in the world and now exporting to 64 countries.

Conventional production of sugar used to involve cutting and burning of sugar cane. The cane was cut by hand, dropped on the soil, dirtied and then cleaned using 4 million litres of water per hour. The chief agronomist decided that this was a wasted resource, and could be saved by harvesting the cane in a different manner. The company looked for a cleaner means of producing sugar and this gave way to the Green Cane project, the industry's first attempt to harvest cane in an ecologically friendly manner. The aim was to lower the environmental impact of production and to lower the cost of production. This later led to the adoption of green sugar cane practices that were adopted by 90% of sugar cane growers in Brazil.

Sugar cane
Source: Enviro2B

The first step taken by the company was to change its harvesting of green cane to avoid burning and cleaning. Subsequently, the company decided to abolish chemical fertilisers and pesticides. They adopted a biodiversity approach which imitated the natural regulatory role of forests which they realized had interconnected sophisticated systems between plants and insects. The company realized that the insects inside the forest were not attacking plants, but they were the same insects that attacked the sugar cane. They began to transfer a natural approach to create the basis of a new production system which has a minimal environmental impact, is more rational and more efficient. The focus is not on protecting the crop, the focus is on engineering an environment and recreating an integrated ecosystem on the whole. This resulted

55 Leontino Balbo "Is this the future of global food systems?" www.youtu.be/G-pr0cYzuDQ.

in creating an ecosystem that incorporated the sugar cane crop. Using this system there is no need to fertilise the crop, as the system naturally regenerates and feeds soil life and this then takes care of the cane's nutrition and immunologic system. This reduced disease on 20,000 hectares of sugar cane.

The company recognised that the natural ecosystem provides all conditions for crop growth and eliminates the potential for plagues and diseases. Whilst at the same time, providing environmental services, such as water preservation, improving soil fertility, bringing back flora and fauna, biodiversity and absorbing carbon. One of the most interesting results in the application of revitilising agriculture is the radical change of soil structure.

The company estimates that they have achieved a higher fertility soil type than existed before the cane had been planted. The soil structure is a naturally rich and retains 4 times more water than conventional soil, in a way that the company now produces 20% more of conventional sugar cane without irrigation. Additionally, the soil helps the water life cycle. The soil has the capacity of filtrating and storing water over 6 time cycle, in a way that the water is sufficient to feed the crop, to evaporate and then to be transferred to the clouds and supply the aquaflor. The rivers on the farms have increased by 30%. Besides becoming more fertile and providing much better yields, the soil was rebuilt by the activity of fungus, bacteria as well as hundreds of different species of insects and it now presents a resilience. Researchers discovered that the fungus acted as a natural connector in the soils, they are translators of different ways of communications between different forms of vegetation, insects and bacteria.

Finally, the company reviewed its technological processes, given that 90% of the machinery did not fit within the existing systems designs. They approached the problem by looking at soil demands, then customizing in the workshop equipment like tillers, cybing tips and harvesters. This was in order to provide and guarantee that the soil is biodiversity friendly the harvesters are equipped with metal tracks which avoid putting pressure on the soil. Trucks now have ultra high filtration tyres 20 psi of pressure, guaranteeing that the soil is not going to be compacted and that under the strain there will be enough comfort level for all life forms promoting the soil rebuilding.

The production model is circular, they harvest the cane, the cane is processed and then they have the production of alcohol, sugar, electricity. They take back all organic waste product and use this to apply vinesses, an organic fertilizer and nutrient which boosts soil and lifeform activity. The harvesting therefore uses sophisticated harvesting practices with natural processes to feed life forms, creating a closed cycle in which nothing is lost.

As a result of the circular economy, the production environment became much more resilient, weather is unpredictable, but they achieve more tons of cane per millimetre? of rain. So compared to 30 years ago more than double, compared to 10 years before efficiency increased by 15% After 1 year of organic production, they extracted 45,000 tones of CO_2 from other activities, they are not just carbon neutral, but carbon sink. Today the farms has over 340 species of animals, more than 50% than the national parks.

It is not what you plant that is the problem, it is how you produce the product.

6. WHO IS CONCERNED WITH AGRICULTURAL WASTE?

All actors across the Food Supply Chain should be concerned on the issue of agricultural waste, which can help to drive efficiencies and save costs.

For this reason, it is important to involve colleagues right across the supply chain to ensure a consistent plan of action for waste reduction. Further, within each step of the supply chain such as at the farm level, all staff must be trained in proper waste management to ensure good commitment to the strategy and responsibility.[56]

This includes day-to-day disposal of different waste types as well as how to deal with rare waste management incidents such as toxic chemical or oil spills. Indeed, novel approaches to waste management are often devised by staff who work in the field and deal with waste on a daily basis.

- **At the farm level:**

  - Farm manager, appointed waste manager, harvest/picking workers

- **At processing and packing sites:**

  - All staff involved in sorting, grading, cooling, cleaning, processing and packing produce
  - Staff involved in purchasing produce
  - Staff involved in purchasing other materials e.g. packaging inputs
  - R&D staff
  - Quality Assurance staff
  - All office staff

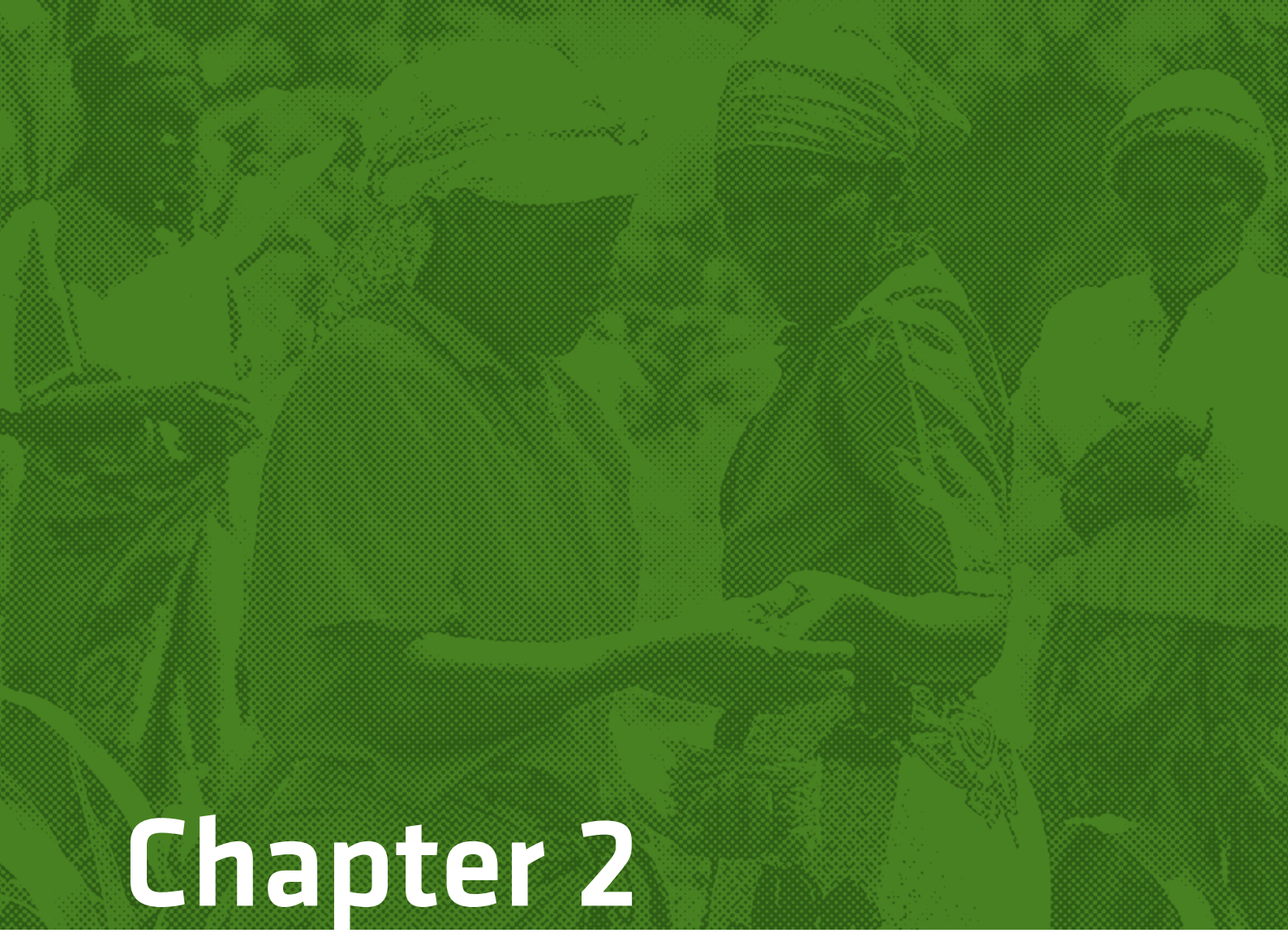
- **Transport and distribution:**

  - Staff involved in selecting vehicles and planning delivery schedule
  - Staff responsible for loading produce
  - Drivers

- **Retailers**

  - Purchasing staff
  - R&D staff
  - Quality Assurance staff
  - Shop floor staff – including appointed waste manager

56 C. Strotmann *et al.*, "A participatory approach to minimizing food waste in the food industry – A manual for managers", *Sustainability* 9 (66), 2017 pp. 22..



Chapter 2

Evaluation of waste production

1. EVALUATION OF WASTE PRODUCTION

1.1. What waste?

Waste from horticultural production can range from from organic waste generated on farm (from plants and animals) to household waste (from workers), to non-organic waste (glass, metals, plastics used in packaging) and hazardous wastes such as chemicals and fuels used throughout the production process.

To deal with waste efficiently on a site, we need to identify the different waste streams by focusing on the management of organic and non-organic waste generated from 5 key areas, which we refer to as the 5 M's.

Some examples of the types of waste that can be covered are included below:

1. Mainland (waste generated on the farm)

Organic waste sources	Non-organic waste sources
• Runoff liquid from irrigation • Waste liquid used for cleaning produce • Animal waste • Vegetation and plant waste such as cuttings, branches, leaves	• Chemical fertilisers • Chemical pesticides • Chemicals used for production • Chemicals used for cleaning

2. Manpower (workforce)

Organic waste sources	Non-organic waste sources
• Human waste • Left over food • Liquid waste from cleaning utensils • Liquid waste from baths and showers	• Personal Protective Equipment (PPE): gloves, hats, masks, overalls, aprons • Glass, metals and plastics

3. Materials (harvest and processing)

Organic waste sources	Non-organic waste sources
• Excess product • Damaged product • Waste liquid from washing product	• Damaged packaging • Damaged plastic wraps and containers • Damaged tins, glass jars and lids • Damaged cardboard, labels

4. Method (product design and storage)

Organic waste sources	Non-organic waste sources
• Discarded product which does not meet client specifications	• Excess packaging • Damaged crates and bags • Damaged pallets • Chemicals used in production • Fuel used in transportation

5. Machinery (and equipment)

Organic waste sources	Non-organic waste sources
• N/a	• Oils and fuels • Spare tyres, • Irrigation pipes • Polytunnel plastic

1.2. Food waste or food loss (spoilage)?

Food is lost or wasted throughout the supply chain, from initial agricultural production down to final household consumption. The FAO estimates that roughly one-third of food produced for human consumption is lost or wasted globally, amounting to about 1.3 billion tons per year.[57] This not only constitutes a waste of food, but also a waste of the natural resources used in food production and the greenhouse gas emissions associated in that process.

We only use the terms 'food waste' and 'food loss' when we are speaking about products which are destined for human consumption. This does not include any feed and parts of products, which are not edible. We would often refer to this latter type

57 FAO, 2011 "Global food losses and food waste – Extent, causes and prevention" Rome www.fao.org/docrep/014/mb060e/mb060e00.pdf.

of waste as organic waste. The definition also excludes the wasted natural resources used in the production process such as water.

Within these definitions, the Swedish institute for Food and Biotechnology (SIK) refers to 'food losses' or 'spoilage' as a decrease in edible food for human consumption along the Food Supply Chain (FSC):

- The term 'food loss' is used to describe waste which takes place at the initial stages of the food chain during different production, post-harvest and processing stages.
- The term 'food waste' or 'spoilage' occurs at the other end of the food chain (retail and consumption) and specifically relates to retailer and consumer behaviour.[58]

1.3. Poor practices leading to food loss (harvesting, handling, storage, processing and distribution)

Research suggests that the causes of food loss in the Food Supply Chain (FSC) in producer countries is mainly due to financial, managerial and technical limitations in harvesting techniques.

As well as poor storage and cooling facilities in difficult climatic conditions. This is often exacerbated by weak infrastructure, packaging and marketing systems. Within the horticultural industry, the FAO has identified the following causes of food loss linked to the different stages of the FSC:[59]

- Agricultural production: losses occur as a result of mechanical damage and/ or spoilage during harvest operations (eg. threshing or fruit picking) and sorting and discarding of crop. There are also market distortions, where production exceeds demand so that producers can deliver on agreed quantities. This is a sort of contingency plan against adverse weather conditions or pest attacks, where farms grow larger quantities of produce than needed. Surplus crop can be used for animal feed, but this does not always financially offset the cost of production.

- Post-harvest handling and storage: this includes losses due to spoilage and degradation during handling, storage and transportation between the farm and the processing units. The losses are due to poor storage facilities and lack of infrastructure for transport, storage and cooling. These can be explained by the deterioration of perishable crops in warm and humid climates, as well as seasonality which leads to gluts in production.

- Processing: refers to losses as a result of spoilage and degradation during the packing and transformation process, e.g. juice production and canning. Losses may occur during the sorting process (if the product is not the right size,

58 *Ibid.*

59 *Ibid.*

colour or texture) and does not fit specification making it unsuitable suitable for processing. Damage of the product can also occur during washing, peeling, slicing or boiling.

- Distribution: specifically covers loss and waste in the market system at wholesale markets, supermarkets, retailers and wet markets. Industrialised countries high quality standards (weight, size, shape and appearance) lead to rejections by supermarkets at the farm gate and can cause considerable losses to producers.

- Consumption: this includes losses and waste during consumption, which occurs at different stages of the FSC and is closely linked to affluence levels of consumers. For example, consumers in Europe and North America food waste is approximately 95-115kg/ year, whilst in Sub Saharan African and South / South East Asia the figure is only 6-11kg/ year. (See figure 9).
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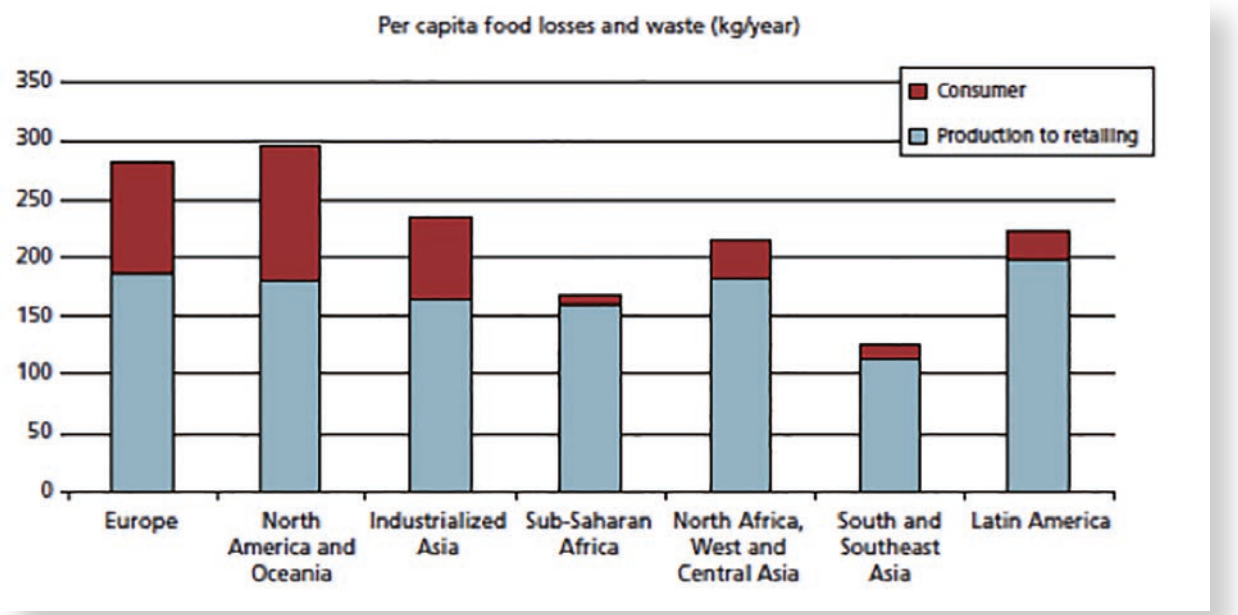


Figure 1: Per Capita food losses and waste, at consumption and pre-consumption stages in different regions
Source: FAO[60]

Interestingly, when it comes to FSC food losses, these are just as high in industrialised countries as they are in in developing countries. The key difference is the stage at which food loss occurs. In developing countries, over 40% of loss occurs at post harvest and processing levels, whilst in industrialised countries, over 40% of food loss occurs at retail and consumer levels.[61]

60 FAO, 2011 "Global food losses and food waste – Extent, causes and prevention" Rome. Page 5, Figure 2 www.fao.org/docrep/014/mb060e/mb060e00.pdf.

61 *Ibid.*

Within the horticultural context, this loss is mainly due to post harvest grading caused by quality standards set by retailers and 15-30% of purchases being discarded by consumers. FAO estimates that losses in agricultural production from the developing regions dominate the total loss across the FSC, as seen below.

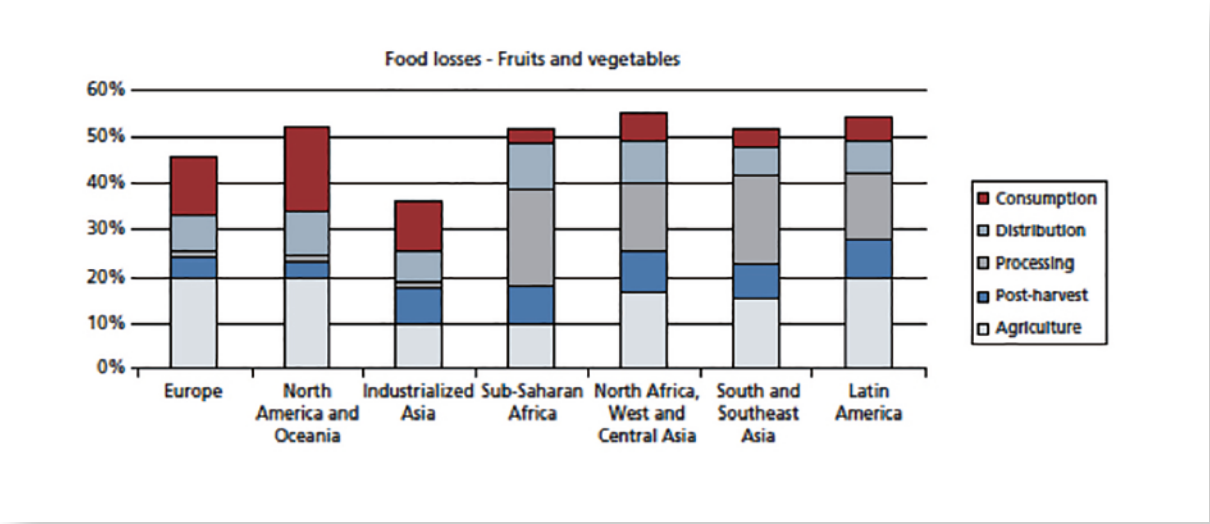


Figure 2: Part of the initial production lost or wasted at different stages of the FSC for fruits and vegetables in different regions
Source: FAO[62]

62 FAO, 2011 "Global food losses and food waste – Extent, causes and prevention" Rome. Page 5, Figure 2 www.fao.org/docrep/014/mb060e/mb060e00.pdf.

2. THE COST OF WASTE

A growing population means that there will be a growing demand for agricultural products. Research by the OECD (2015) suggests that we will have to produce almost 50% more food by 2030.[63] Growing concerns around soil erosion, water scarcity, degraded lands and ecosystems, means that we cannot afford to lose or waste food.

There are multiple effects of post-harvest losses which extend beyond the loss of the actual crop to include loss of environmental and human resources. This has serious implication on food security as it is bound to affect the affordability and availability of fresh produce to consumers.

The key concerns are:

- Wasted water resources: The total volume of water used each year to produce food that is wasted is (250km3), equivalent to the annual flow of Russia's Volga River or 3 times the volume of Lake Geneva. Agriculture is the largest consumer of freshwater, and accounts for 70% of the world's freshwater withdrawals from rivers, lakes and aquifers (up to 90% in some developing countries). It takes between 1,000 to 3,000 litres of water to produce 1 kg of rice and 1 litre of water to produce one grain of corn.[64]

- Waste of land and depletion of fertile soils: 14 billion hectares of land – 28% of the world's agricultural area is used annually to produce food that is wasted or lost.[65] This means that the future capacity of soils to produce goods or services is being depleted for no reason. UNEP estimates that each year an estimated 24 billion tonnes of fertile soil are lost due to erosion and global estimates suggest that 24% of all used land is degraded to some degree. The amount of arable land available per person will decrease to 1500m² by 2050, down from 4000m2 in 1961.[66]

- Increased cost of inputs: According to the First Resolution of the Abuja Declaration on fertiliser, African governments have to increase fertiliser use from the average of 8 kg of nutrients per hectare to 50 kg of nutrients per hectare by 2015 to achieve good yields. Conventional farming relies heavily on intensive use of chemicals, namely synthetic fertilizers and pesticides. In Sub-saharan Africa a bag of fertiliser can cost between USD$35 – USD$55 per 50kg and depending on the country, type of fertiliser and crop. In some cases, this can represent as much as 30% of the total costs on a smallholder farm. Added to this is the pollution that can arise from increased fertiliser use.[67]

63 OECD, 2015, www.oecd.org/agriculture/water-use-in-agriculture.htm.

64 UNFPA, "Water: a critical resource", New York, 2002, lwvlaplata.org/files/unfpa_water_1_.pdf.

65 FAO, 2017 Food wastage: Key facts and figures: www.fao.org/news/story/en/item/196402/icode/.

66 Foundation on Future farming, Convention agricole et rurale ARC2020.

67 According to local NGO Farm Inputs Promotions Africa (FIPS).

- Exarcebated food insecurity: The global volume of food wastage is estimated at 1.6 billion tonnes of "primary product' of which the edible part of this amounts to 1.3 billion tonnes.[68] In 2010 about 925 million people were hungry and many more food insecure. For those who are food insecure the priority is to have access to food products that are nutritious, safe and affordable. Food insecurity is often more a question of access (purchasing power and prices of food) than a supply problem. Food waste (excluding fish and seafood) runs to the tune of USD$750 billion a year. Improving the efficiency of the food supply chain could help reduce the cost of food to the consumer and thus increase access to nutritious food.[69]

- Climate change impact: Food wastage carbon footprint is estimated at 3.3 billion tonnes of CO_2 equivalent of GHG emissions released into the atmosphere.[70] A low percentage of all food waste is composted: much of it ends up in landfills and represents a large part of municipal solid waste. Methane emissions from landfills represents one of the largest sources of GHG emissions from waste.

68 FAO, 2017 Food wastage: Key facts and figures: www.fao.org/news/story/en/item/196402/icode/.

69 FAO. 2011. Global food losses and food waste – Extent, causes and prevention. Rome.

70 FAO, 2017 Food wastage: Key facts and figures: www.fao.org/news/story/en/item/196402/icode/.

3. THE ENVIRONMENTAL BENEFITS OF PROPER WASTE MANAGEMENT

3.1. Waste management is profitable

Global waste challenges imply that we need to **become much more resource efficient, and look at options for reducing and reusing waste.** This is relevant for all sectors of the economy, but especially for agriculture given current food loss and waste globally. And given the massive pollution that results from the increased use of fertiliser and waste generated.

The environmental benefits from proper waste management can be summarised as:

- **Reduced GHG emissions generation**

Waste prevention, recycling and reuse and energy recovery from spoilt food could reduce the amount of waste sent to landfill and result in GHG Emissions savings along the FSC. Waste management can be transformed into a net carbon reducer for example through methane and gas collection. The World Bank is currently backing projects which support GHG mitigation through food loss and waste reduction, organic waste diversion and the adoption of disposal technologies that capture biogas and landfill gas.[71]

- **Reduced environmental degradation from uncontrolled waste disposal**

Waste contributes to the environmental degradation of air, water, soil and biodiversity. Within a horticultural context, more controls are in place to ensure Zero Discharge of Hazardous Chemicals (ZDHC) into freshwater bodies across supply chains and reduce other water quality impacts from agriculture.

- **Resource and energy conservation through material recovery**

Sustainable waste management requires we look at waste not as a burden but as a recycling opportunity. The concept of the circular economy, means avoiding waste production and using waste as a resource wherever possible. For example, producing aluminium from recycled aluminium requires 95% less energy than producing it from virgin materials. Currently some EU Member States recycle more than 80% of their waste, which indicates the possibility to use waste as one of the key resources. As the cost of virgin materials and their environmental impacts increases, so it is expected that the value of secondary materials will increase.[72]

71 www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

72 World Bank, 2012, What a waste: A global review of solid waste management.

3.2. The economic benefits of proper waste management

There are key economic opportunities that can arise from proper waste management, these include:

- **Access to international financing**

Waste agricultural biomass can be of high value as the energy that it contains can be recovered. Accrosing to UNEP, 5 billion metric tons of biomass is generated every year from agriculture. This is equivalent to about 1.2 billion tonnes of oil – 25% of current global production. (repeated chapter 1) The conversion of agricultural biomass waste into energy is that it is widely available, renewable and free.

In the carbon finance area, the World Bank currenly has 38 municipal waste management projects plus additional projects of agricultural waste. Since 2000, the bank has been committed to Carbon finance of the purchase of reductions in greenhouse gas emissions, including methane from projects.

These projects can be small scale, and cover landfill gas capture, aerobic landfill, methane avoidance (aerobic composting, methane digesting, refuse derived fuel an incineration with an without energy recovery).[73]

- **Generating alternative income streams from waste**

Food is lost during the FSC because of spoilage and discarded product down the production line. Losses can occur where final products are the wrong weight, shape or appearance and these do not meet the specifications of the buyers, therefore they are discarded, despite the fact that these continue to be safe and nutritional. The development of markets for sub standard products and/or transformed products, eg. such as canned tomatoes, is increasingly being tapped into to generate additional income.

- **Revenues from recovered energy and materials**

The global market for recycled materials has increased significantly. The world market for scrap metal for example is estimated at 400 million tonnes annually and around 175 tonnes annually for paper and cardboard (UN Habitat 2009). This represents a global value of at least $30 billion per year.[74] Meanwhile the EU is creating a market for food waste to be turned into organic fertilisers and for former food stuff which is spoilt to be turned turned into animal feed. The aim of this initiative is to develop a circular economy which reduces food waste, avoids burning or landfills and generates an additional income revenue.

73 World Bank, "Solid Waste Management" 7 April 2017 www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

74 *Ibid.*

- **Improved infrastructure, transport and marketing facilities**

In many cases within the horticultural industries of ACP countries, the food processing industry does not always have the capacity to process and preserve fresh farm produce to be able to meet demand. This is often as a result of seasonal production and the cost of developing processing facilities that are not used all year round.[75]

Investment in storage, handling facilities and infrastructure from the private and public sector is helping to reduce the time it takes to transport crops and reduce spoilage. Increasingly linkages are being developed between processors and farmers across different regions, to ensure that there is adequate supply of produce all year round. Marketing cooperatives can provide a central point for assembling produce from small farmers and preparing food for distribution.

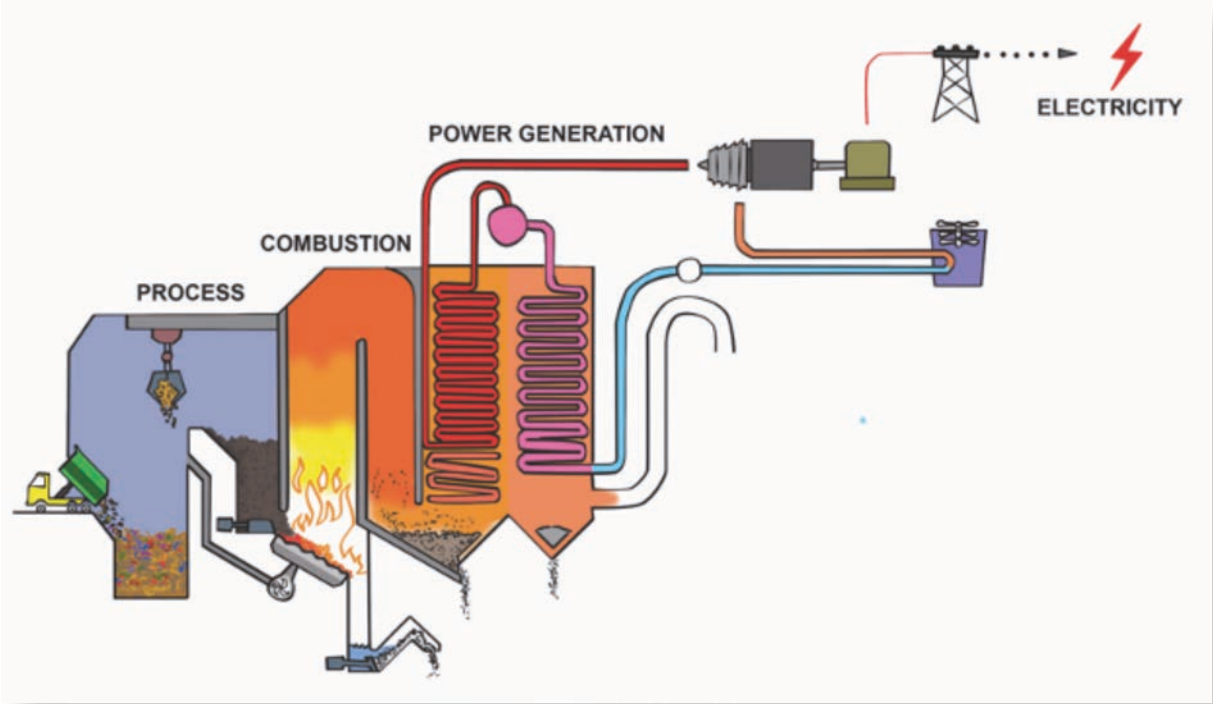


Illustration of power generation at a waste plant
Source: www.sytraival.com/valorisation-energetique/unite-valorisation-energetique.php

75 FAO. 2011. Global food losses and food waste – Extent, causes and prevention. Rome.

3.3. The social benefits of proper waste management systems

Poor waste management can have negative impacts on both environment and public health. These can result from different handling and disposal activities resulting in soil, water and air pollution. Below are some key examples of the benefits of establishing proper waste management systems:

- **Promoting greater sanitation for workers and local communities**

Untreated waste may cause serious health problems for populations surrounding the area of disposal. Resource recovery in most developing countries relies heavily on informal workers who sort and receycle 15-20% of generated waste.

By focusing on H&S training and providing the right type of PPE, workers can be protected in their jobs and waste disposal sites will check that workers are apt to carry out this type of work. By ensuring that a site is legally compliant, not only environmentally but also socially, it is possible to ensure that pickers are integrated into a formal system, where they are properly remunerated and they have the right to work.

The World Bank is currently developing projects to integrate pickers into the formal system and provide safe working conditions, enacting child labour restrictions.[76]

- **Up-scaling skills in the conservation of harvested products, particularly in small-scale agriculture for consumption or sale**

At the farm gate, producers are being taught how to dry foods and conserve produce to keep its nutritional value for as long as possible. Additionally, more training is being given in packaging and safe storage of crops to avoid spoilage and or contamination. This impacts not only on food security but also on livelihoods. There are also several initiatives to show women how to preserve mangoes and other fruits and to create value addition of products such as jam.

- **Improved management of resources, leading to greater efficiency in farming and improved livelihoods**

Waste can make a big contribution to economic growth and job creation. Research suggests that full implementation of EU waste legislation would save €72 billion a year, increase the annual turnover of the EU waste management and recycling sector by €42 billion and create over 400 000 jobs by 2020. (BIO Intelligence Service, 2011; EC, 2012)[77].

76 World Bank "Ending the Vicious Cycle of Open Dumps; Improving Waste Pickers' Lives" www.worldbank.org/en/news/feature/2013/11/08/ending-open-waste-dumps-changing-pickers-lives.

77 www.euro.who.int/__data/assets/pdf_file/0003/317226/Waste-human-health-Evidence-needs-mtg-report.pdf?ua=1.

3.4. Case Study – Low cost production of charcoal briquettes from organic waste in Kenya[78]

Kenya has three sources of main energy: wood fuel, petroleum and electricity, accounting for 70%, 21%, and 9% of the country's total energy use respectively.

In rural areas 34% of households reportedly use charcoal as a primary source of fuel, whilst in urban areas this increases to 82%. A continued reliance on wood-based charcoal and clearance of land has led to deforestation at an alarming rate.

Of Kenya's 30,000 square kilometers of tree cover, more than 8 percent was lost between 2001 and 2014.[79]

In 2012, the Rumuruti Forest Association set up a project with 7 cooperatives to turn organic food waste into energy. The cooperatives lacked infrastructure and technology for proper composting and recycling, and organic waste represented little monetary value. This project presented an opportunity to effectively deal with organic waste and provide an additional source from the sale of charcoal. With the cost of charcoal in urban areas being US$17/bag and in rural areas being US$5, this was an opportunity to create an income stream for local farmers and pickers and to provide charcoal to some 5,000 households in the area.

A top-lit kiln design was developed for low-cost production (less than US$30 apiece), with minimal requirements needed for both production and maintenance (e.g. no welding). Rural farmers and urban waste-pickers were trained to operate the kilns safely.

The community project which covered 7 villages, today counts about 50 kilns, amounting to a full-time production capacity of about 2 tons/day of charcoal. The Rumuruti community, partnered with a briquette company to package and market the charcoal in the nearby town Nyahururu, where the price of charcoal is higher than the rural areas and sells at USD$9.

78 KUNG Kevin, Department of Biological Engineering and SENSEable City Laboratory " Low-Cost Production of Charcoal Briquettes from Organic Waste, http://web.mit.edu/~kkung/Public/paper.pdf.

79 www.news.mongabay.com/2016/04/kenya-aims-reverse-deforestation-plant-20-million-new-trees/.

Figure 11: Carbonization process using the top-lit kiln design
Source: Department of biological engineering[80]

(a) The main kiln has an open top and many small holes at the bottom. The adapter has an alternatingly ridged/grooved bottom (b) as well as a star-shaped opening at the top (c). To operate the kiln, the biomass is set on fire from the top (d), and once the fire has spread all around, the main kiln is covered with the adapter (e), immediately followed by the chimney (f). After about 20 minutes of pyrolysis followed by about 1-2 hours of cooling, charred biomass is recovered (g).

80 KUNG Kevin, Department of Biological Engineering and SENSEable City Laboratory, "Low-Cost Production of Charcoal Briquettes from Organic Waste",http://web.mit.edu/~kkkung/Public/paper.pdf.

4. DEFINITION OF THE 4 Rs

The concept and promotion of the three Rs was created to help combat the drastic increase in solid waste production across the Food Supply Chain (FSC) and today includes a 4th R which stands for 'Recover'.

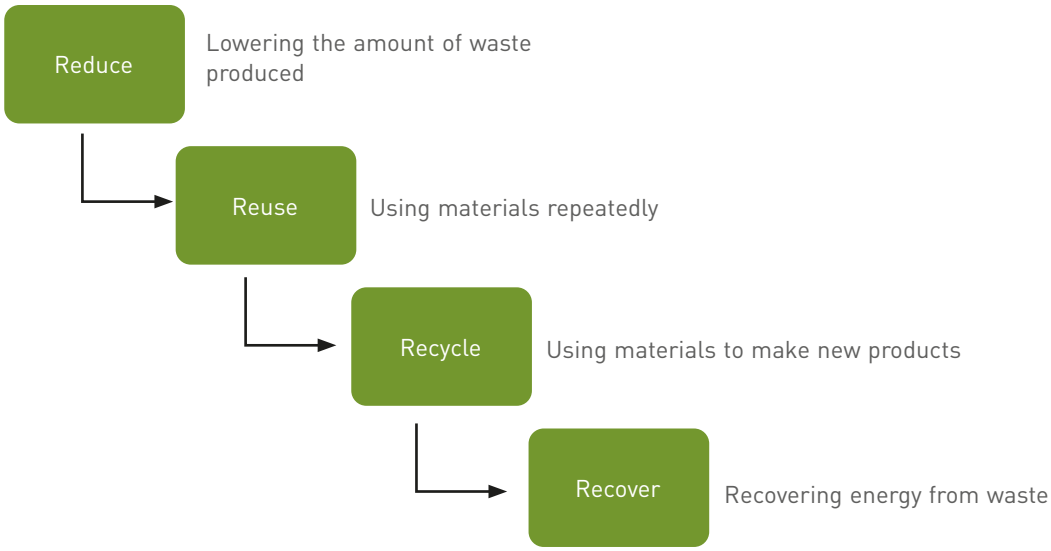


Figure 12: The 4 R's

- **Reduce**

Reduce is the most important part of the FSC waste strategy. In order to reduce the amount of waste produced, it is essential to focus on the source of the waste, at the point at which it is generated. Source reduction is when products are produced, designed, manufactured, packaged, and used in a way that limits the amount or toxicity of waste created. The first goal of source reduction is simply to reduce the overall amount of waste that is produced. The second goal is to conserve resources by not using raw, virgin materials. In other words, by following source reduction, fewer raw materials will have to be used to produce products. Aluminum cans are also a good example of source reduction because they are now made with 1/3 less aluminum than they were twenty years ago.

- **Reuse**

The second most important strategy is to Reuse, which is when an item is cleaned and the materials are used again.

There is one main way that the concept of reusing can be applied to reduce waste in the FSC. Namely, through the packaging of products that can be used repeatedly instead of a version that is only used once and thrown away.

For example, certain fruit juice companies use glass bottles to hold their products and promote consumers to return the bottles. The company then cleans and refills the

bottles for sale. On average a beverage glass bottle can make about 15 round-trips between the manufacturer and the consumer before it is damaged and recycled.

- **Recycle**

Recycling enables the materials that are thrown away to be used again by making them into new products. The most common forms of waste that are recycled by households are paper, metals and plastics. However, within the organic, food waste can be mixed with farm waste, shredded and used to make compost. The diagram below from the food waste network, illustrates how high quality fertilizer is made. Whereby organic waste is enclosed composting vessel for around 2 to 4 weeks, under high temperatures to ensure any pathogens in decaying food are destroyed. The resultant material is matured in piles for several weeks before being screened for contaminants or larger pieces. The final result is nutrient-rich fertiliser which is a valuable can be used to improve soil and growing plants.[81]

Figure 13: In Vessel Composting (IVC)
Source: The food waste network[82]

- **Recover**[83]

81 www.foodwastenetwork.org.uk/content.html?contentid=12.

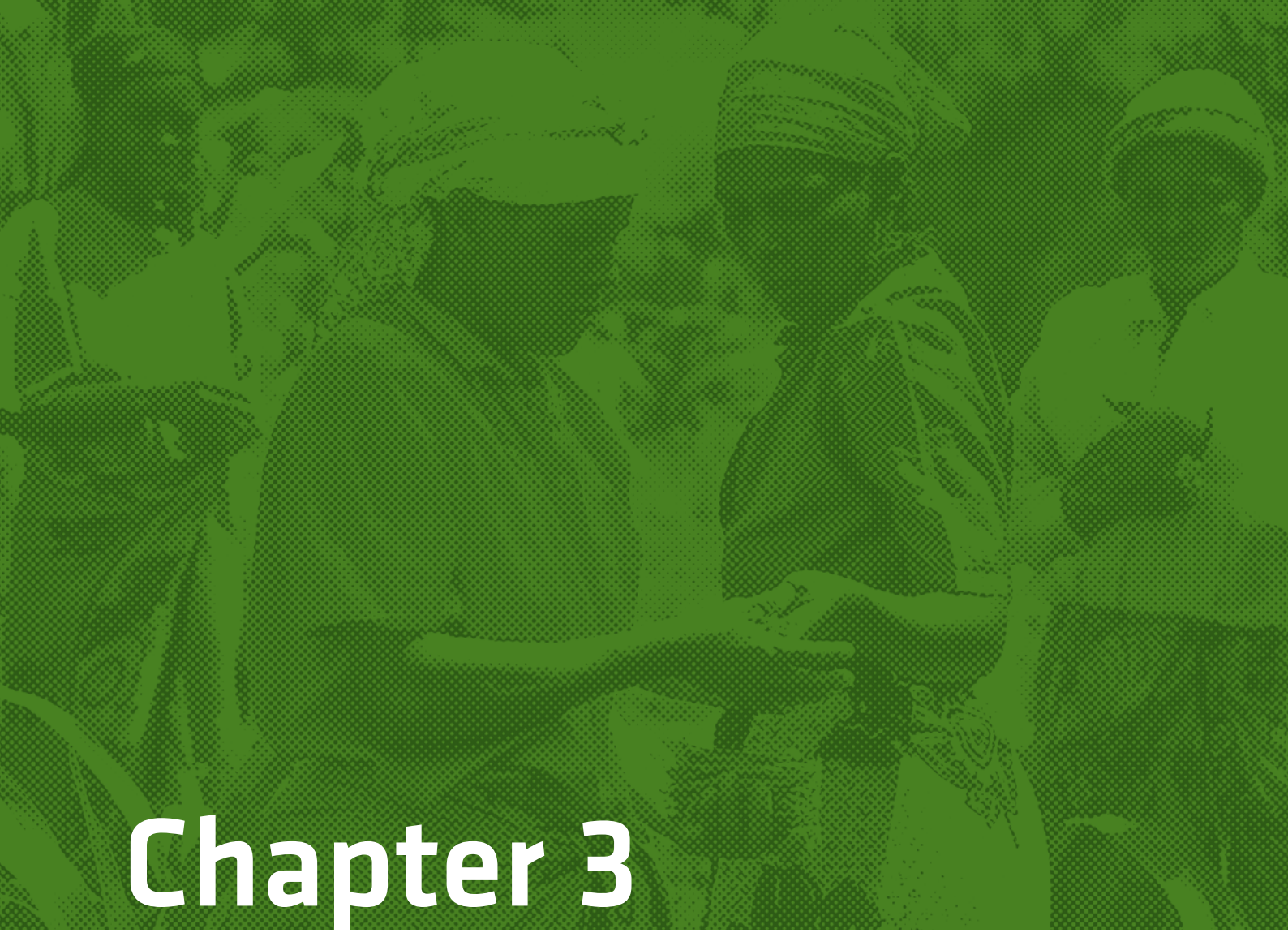
82 *Ibid.*

83 ENVIRONMENTAL PROTECTION AGENCY www.epa.gov/sustainable-management-food/industrial-uses-wasted-food.

There is increasing interest in finding effective means to obtain biofuel and bio-products from wasted food. Recovery covers the conversion of waste materials into alternative energy sources, to alleviate some of the environmental and economic issues associated with waste while increasing the use of alternative energy sources.

Within the FSC, anaerobic digestion is used as a natural process in which microorganisms break down organic materials to create energy. The following organic materials can be processed in a digester:

- Animal manures;
- Food scraps;
- Fats, oils, and greases;
- Industrial organic residuals; and sewage sludge (biosolids).



Chapter 3

Reduction of waste production

1. REDUCTION OF WASTE PRODUCTION

1.1. Common problems and causes of waste in horticulture

Horticulture produces a wide range of waste streams: organic material, plastics from drip system irrigation systems, metals, paper, glass, as well as hazardous chemicals and their containers, fuel, lubricants and oil from motor pumps, tractors and atomizers.

Of these, **the largest volume of waste in ACP countries occurs from fresh food.**[84]

Given that many ACP smallholder farmers live on the margins of food insecurity, a **reduction in food losses and waste** could have an **immediate and significant impact on their livelihoods**.[85]

The causes of food losses and waste are mainly connected to financial, **managerial and technical limitations** in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems.

Taking measures to reduce wastage during crop production and post-harvest will often result in **multiple benefits to the grower**. For example, for a grower who implements good field hygiene and sanitation practices, crops are less likely to suffer from food safety issues such as contamination from animal faeces, crops are more likely to remain in good health with increased shelf life, waste due to spoilage will reduce and in turn, the grower's own income, economic opportunities and resilience may advance.[86, 87]

This chapter explores the different causes of waste production across the horticulture industry and identifies solutions to these problems.

84 Banque mondiale, 2012, What a Waste. A global review of solid waste management. The World Bank Urban Development Series. Disponible à l'adresse http://documents.worldbank.org/curated/en/302341468126264791/pdf/68135-REVISED-What-a-Waste-2012-Final-updated.pdf.

85 FAO (2011) Global food losses and food waste – Extent, causes and prevention.

86 Dixie, G. (2015) Horticultural Marketing. FAO, Rome.

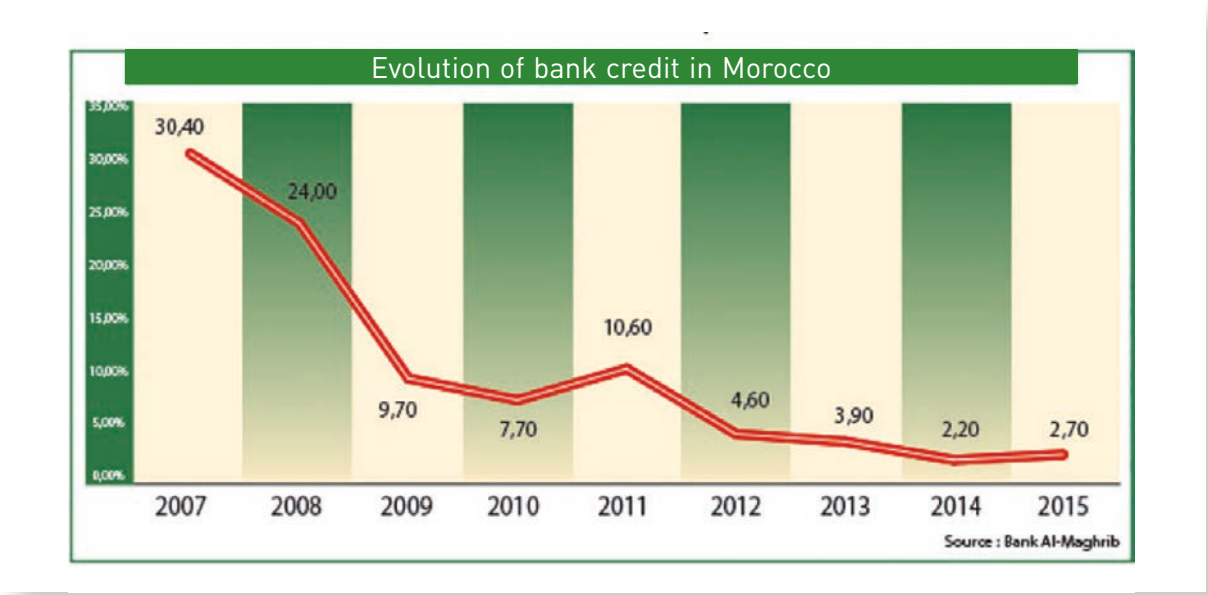
87 Reducing global food waste and spoilage (2014) A Rockefeller Foundation Initiative. Assessing resources needed and available to reduce post harvest food loss in Africa. The Rockefeller Foundation and Global Knowledge Initiative. Available at http://postharvest.org/Rockefeller%20Foundation%20Food%20Waste%20and%20Spoilage%20initiative%20Resource%20Assessment_GKI.pdf.

1.2. Problems and solutions to waste during the harvesting process

Once harvested and separated from their sources of water and nourishment, a horticultural crop will inevitably perish. The role of proper postharvest handling is therefore to delay this for as long as possible.

Horticultural managers must possess **many skills** to succeed in this including a keen appreciation of horticultural diversity. For example, **spinach, tomatoes, bananas and potatoes each have their own particular requirements**. The optimum postharvest management of horticultural products is not the same for all products. Growers, wholesalers, exporters and retailers must all be aware of the specific needs of a product to maximize the postharvest shelf life and quality.[88]

Challenges faced by small-scale producers include **lack of credit** for investments in postharvest technology, unreliable electric power supply, lack of suitable transport, storage facilities and/or packaging materials, to name but a few.



Example: Evolution of the bank credit in Morocco

Fortunately, **there is a wide range of simple post-harvest technologies** from which to choose, and many practices have the potential of meeting the special needs of small-scale producers.

Many of the practices included in this manual have successfully been used to reduce losses and maintain produce quality of horticultural crops in various parts of the world for many years.[89]

88 El-Ramady, H., Domokos-Szabolcsy, E., Abdalla, N., Taha, H., and Fári, M. (2015) Postharvest Management of Fruits and Vegetables Storage. In Sustainable Agriculture Reviews (2015) Lichtfouse, E. (Ed.) Springer International Publishing Vol 15, pp. 66-152.

89 Kitinoja and Kader (2015) Small scale postharvest handling practices: a manual for horticultural crops (5th edition). Postharvest Horticulture Series no. 8E. University of California, Davis.

Presented here are some of the most common problems, and solutions, in horticultural post-harvest waste production:

a) Crop is harvested during hot weather and ends up wilting and spoiling. The solution is to carefully plan harvest according to weather and transport availability.

Ideally, harvesting should take place when the crop and the climate are coolest and the plant has the highest moisture content. This is in the early morning but other challenges must also be considered. For example, labour and transport may not be available early in the morning.

If transport is a problem the harvest should be rescheduled to avoid produce being left standing in the field for too long. Specific crops often have **ideal harvest times**. For example, citrus should not be picked until the dew is dry.

The best time for harvesting mangoes is mid-morning, when the latex flow is at a minimum.

According to the FAO,[90] the basic rules to observe are:

- Harvest during the coolest part of the day: **early morning or late afternoon**;
- **Do not harvest produce when it is wet from dew or rain**. Wet produce will overheat if not well ventilated, and it will be more likely to decay. Some produce may be more subject to damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits;
- Protect harvested produce in the field by putting it **under open-sided shade** when transport is not immediately available. Produce left exposed to direct sunlight will get very hot. For example, aubergine and potatoes left exposed to tropical sunlight for four hours can reach temperatures of almost 50 degrees Celsius.
- Produce for local markets can be harvested early in the morning. For more distant markets it may be an advantage (if suitable transport can be arranged) to harvest in the late afternoon and transport to market at night or early the next morning.

90 FAO (1989) Prevention of post-harvest food losses fruits, vegetables and root crops a training manual. FAO Training Series: no. 17/2. Rome.

Shading of the products after harvesting should not be improvised and does not dispense with minimum hygiene requirements, such as isolating the products from the soil. Photo from the COLEACP Manual.

Building on the harvesting site, with light materials, having well-ventilated shelters to quickly put the harvested products in the shade and keep them fresh are precious assets for quality.
Photo: B. Schiffers

b) Crop cannot be harvested in optimal conditions due to hot temperatures. The solution may be to implement precooling systems after harvest and before transportation.

Field heat is usually high and undesirable at harvesting stage of many fruits and vegetables and **should be removed as quickly as possible before any post-harvest handling activity**. In tomatoes, for example, **precooling** minimises the effect of microbial activity, metabolic activity, respiration rate, and ethylene production, whilst reducing the ripening rate, water loss, and decay, thereby preserving quality and extending shelf life.[91]

91 I.K. Arah *et al.*, "Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review", *Advances in Agriculture*, 2016, available at www.hindawi.com/journals/aag/2016/6436945/#B23.

When the packing station is far from the production and harvesting areas, it is possible to keep the products cool by building 'cold rooms' made of light materials.
In this way, the products can be kept for several hours while waiting for transport.
Photo: B. Schiffers

A cheap but effective way of precooling harvested tomatoes can be by **dipping fruits in cold water** (hydrocooling) mixed with disinfectants. These can be used to control mould and as a postharvest management sanitizer. **Chemicals commonly used in tomato precooling which are considered safe for human consumption** are:

- **Sodium hypochlorite**: The active ingredient of most liquid household bleaches, sodium hypochlorite is commonly used when the scale of **postharvest chlorination** is limited. It is used in postharvest management as an algicide, disinfectant, and sanitizer. Sodium hypochlorite is an approved chemical for use in organic postharvest systems by under the USDA National Organic Program (NOP) Rule.

- **Thiabendazole** (TBZ) This is also used as a **fungicide** to control green mold, blue mold, and stem end rot on citrus fruits. It controls Cercospora leaf spot on sugar beets; crown rot on bananas; bluemold rot, bully eye rot, and gray mold on apples and pears; black rot, scurf and foot rot on sweet potatoes; and to control Fusarium (dry rot) in potato storage. It can be used on soybeans to reduce the severity of pod and stem blight such as anthracnose, brown spot, frogeye leaf spot and purple stain.

Washing produce post-harvest can be an efficient means of combining precooling with cleaning produce. According to the FAO,[92] many large fresh-cut processing operations treat and recycle water to conserve this precious commodity. Care must be taken in recycling water so as not to present a new risk of increased microorganisms. Recycled water must be continuously treated and monitored. In situations where the organic material in wash water increases, antimicrobial agents such as chlorine lose their effectiveness in maintaining water quality.

92 James and Ngarmsak (2010) Processing of fresh-cut tropical fruits and vegetables: A technical guide. Food and Agriculture Organisation of the United Nations (FAO).

Produce may also be washed at a small scale in large shallow tanks that allow operators to move the produce freely through the water. In situations where concrete tanks are used they should ideally be tiled. **Frequent changes of wash water are needed in order to effectively remove soil and other foreign matter from the produce.** A better method is to continuously circulate wash water through a filter. Ideally **several tanks should be used** for washing operations. The first tank should be used for the removal of heavy soiling and subsequent cleaner tanks with chlorinated water should be used for final washing. Washing in a sink under continuously running water is only advisable in very small operations, to minimize wasting water – remember, it is not only fresh produce we wish to conserve, but also water!

Figure 14: Field packing structure **(top)** and PolyNet shade structure in India **(bottom)**
Source: Saran *et al*[93]

Whilst this method is effective in removing field heat whilst reducing microbial loads on the harvested fruits, **another method is simply to keep the freshly harvested food in a cool, shaded area**. However, simply placing harvested produce in tree shade is **not a reliable way of reducing field heat** because shade will shift away from the produce as the sun changes its position. Instead, a simple on-farm structure like a small hut made of thatch can be very beneficial for precooling harvested produce.[94]

93 Saran, S., Roy, S. K., & Kitinoja, L. (2010) Appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia-Part 2. Field trial results and identification of research needs for selected crops. In XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 934 (pp. 41-52).

94 Arah, I. K., Kumah, E. K., Anku, E. K., and Amaglo H. (2015) An overview of post-harvest losses in tomato production in Africa: causes and possible prevention strategies. Journal of Biology, Agriculture and Healthcare 5 (16) 78–88.

c) Produce ends up with mould due to dirty harvesting equipment. The solution is to implement proper sanitation of all harvest equipment including harvest bins, knives, pruners and other harvest aids[95]

The effects of using poor harvesting equipment are not always immediate, and may show themselves some days later, when the produce is being presented for sale or is in storage. As a result, farmers may send to market produce which they consider to be good quality, but by the time these arrive at the market the trader sees produce that has deteriorated. This is a double cost to farmers who have paid for transport and may see their product rejected.

An example of this, as reported by the FAO[96], comes from Tonga, in the South Pacific, which used to export capsicum (green pepper) to New Zealand. When the fruit left Tonga they appeared to be in excellent condition but **after four days in a ship they arrived in very poor condition**. The problem was traced to the use of **dirty knives** for harvesting, which carried pathogens that then infected the fruits.

The basic rules to obseve when implementing sanitation are:

- All types of harvest containers which can be reused (plastic, wood or other recyclable materials) must be washed with potable water and sanitized (see Box 2). It is important to remember that waste water can contain nutrients, sediments and plant pathogens and should be prevented from entering the environment without being treated or filtered. Wooden containers are difficult to sanitize adequately and should be avoided. Similarly, single-use cardboard harvest bins and disposable bags that can be used only once should be avoided to minimise waste.

- Never stand or sit on harvest bins.

- Wash as much soil and plant debris as possible from the harvest containers. Stack these on empty crates on top of tarpaulin (large water proof plastic sheets) to keep them clean of soil, before moving them into a packing shed or storage shed.

- Knives, pruners and other harvest aids must be washed and sanitized before use in the field and between uses with various crops.

95 Fontenot, K., Adhikari, A., Graham, C., Malekian, F. and Lewis Ivey, M. (2015) Harvest and field sanitation practices: best practices to ensure on-farm food safety. Louisiana State University Agricultural Center.

96 Dixie, G. (2015) Horticultural Marketing. FAO, Rome.

- Between uses, all harvest equipment must be sanitized and stored in covered areas that are not exposed to rodents, birds, dust or insects. Routine pest inspections and sprays must be conducted.

- Do not store harvest containers directly on the floor or directly against a wall. Harvest containers must be spaced at least 18 inches away from the walls of storage facilities.

- Routine cleaning and equipment maintenance can help prevent microbial contamination of fresh produce and prevent the movement of plant pathogens between fields; power wash or use very hot water to remove as much soil and plant debris as possible from farm implements (tractors, cultivators, etc.). Consider washing equipment between fields and after all harvests.

Box 1. Reusable vs. disposable: an environmental debate

Farmers may question what is better for the environment: single-use items that are disposed of immediately after use, or reusable items, which must be properly sanitized with water and cleaning fluid. There is no simple answer to this: it depends on the materials being investigated, their use, and the final waste treatment of either (a) the single use item or (b) the waste water produced from cleaning the reusable item.

In general, if water is used sensibly and wastewater is treated, it is more environmentally friendly to use reusable items. This is because they create less waste over the long-term, and the greenhouse gas (GHG) emissions associated with their production are lower when averaged out over their lifetime, compared with single-use items.

Some notable exceptions may occur however. For example, if using reusable plastic packing crates, there are transport emissions associated with returning them to the user.

Therefore **if produce is being transported over a very long distance, it may be more suitable to pack in lighter, single-use cardboard boxes**, which can be recycled at their end-of-life, do not create GHG emissions from return transport (as they are not returned) and generate fewer GHG emissions during produce transport due to their lighter weight compared with returnable plastic crates. However, further factors can deepen the debate here – for example, it may be that plastic crates can carry more produce per pallet and therefore per truck load, due to their superior strength and stackable nature, compared with cardboard boxes. In this case, the truck can be filled to a higher % of its weight capacity, meaning that greater transport efficiency is achieved. In general, for shorter distances, returnable, reusable plastic crates make more environmental sense.

We will re-visit the case study of returnable plastic crates later on in this chapter. For information on good wastewater treatment systems, see Chapter 5.

Source: www.francetvinfo.fr/monde/afrique/rwanda/dechets-urbains-une-gestion-laxiste-qui-fait-des-ravages-en-afrique_3062751.htm

Box 2. Simple Protocol for Sanitizing Harvest Bins and Harvest Aids[97]

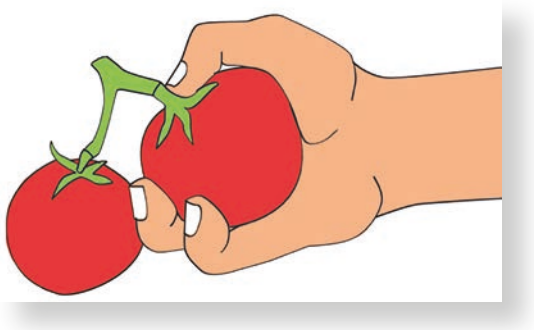
Step 1. Rinse all loose soil and debris from the harvest container or harvest aid with potable water.
Step 2. Wash harvest containers or harvest aids with soap and warm to hot potable water.
Step 3. Before adding a sanitizer such as bleach, determine the water pH using a pH test strip or a pH meter. The water pH should be between 6 and 7.5.

Step 4. Place 1-2 tablespoons of common household bleach (5.25-6 percent active ingredient, nonscented and splashless) per 4 litres of potable water into a pail, bucket or sink. This equals a 100-200 parts per million (PPM) which is used to measure chemical concentration.
Step 5. Dip the nonporous harvest container or harvest aid into the sanitizing solution for 2 minutes. Porous containers will require a higher concentration of household bleach (600 ppm).
Step 6. For porous surfaces, rinse with potable water.
Step 7. Allow bins and harvest aids to air dry before using.
Step 8. Store sanitized containers appropriately.
Step 9. Record when and how you conducted this procedure, including the date, time and sanitizer concentration, in your record book.

Note that it is important to adequately treat wastewater before releasing back out into the environment; see Chapter 5 for good wastewater treatment mechanisms.

97 Fontenot, K., Adhikari, A., Graham, C., Malekian, F. and Lewis Ivey, M. (2015) Harvest and field sanitation practices: best practices to ensure on-farm food safety. Louisiana State University Agricultural.

d) Produce is poorly handled or poorly selected during harvest. One solution is to improve harvesting sanitation, selection and technique of all farm labourers[98]



- Pickers should be trained in personal hygiene for food handling, e.g. they should have short nails, clean hands and wear correct PPE to ensure that food is not contaminated or damaged during picking.

- Pickers should harvest with care, by snapping, cutting or pulling the fruit or vegetable from the plant in the least damaging manner. The tips of knives should be rounded to minimize inadvertent gouges and excess damage to perennial plants.

- Do not harvest produce contaminated with faeces (human, animal or bird).

- Produce that is bruised, produce that has been damaged by insect feeding, rodents or birds and produce that is diseased should be separated from healthy or undamaged products during harvest. Depending on the severity of the damage, this produce could be used for an alternative market, value addition products or used for creating compost.

- Remove as much soil or plant debris from the produce before it leaves the field.

e) Crop is badly bruised during harvest and ends up as waste. One solution is to improve the selection and use of field containers.

- Containers should be easy to carry by the harvest worker while moving through the field.

- Using bags or baskets attached to the waist or shoulders of the harvest worker enables both hands to remain free. Such bags or baskets can be used for firm fruits like citrus but not for soft or delicate fruits or vegetables like beans. They should also be made of a waterproof material to ensure that they can be cleaned in a similar way to crates. Where possible disposable bags should be avoided.

98 FAO (1989) Prevention of post-harvest food losses fruits, vegetables and root crops a training manual. FAO Training Series: no. 17/2. Rome.

- When using bags it is preferable to also be able to open from the bottom so that the produce can be let out gently, rather than up-ending the bag; containers must be emptied carefully to minimize drop heights and fruit-to-fruit damage.

- Plastic buckets or similar rigid containers are suitable for harvesting fruits that are more easily crushed, such as tomatoes. The containers should be smooth, with no sharp edges to damage the produce.

- Baskets are often used for harvesting but may have sharp edges or splinters that can injure produce. If they are not sturdy, they may bend out of shape when lifted or tipped – especially if they are large – and damage the contents.

- Commercial growers may use bulk bins, usually of 250 to 500 kg capacity, where crops such as apples or cabbages are sent to large-scale packing houses for selection, grading and packing.

f) The crop is not always harvested at its optimal maturity. One solution is to improve harvest timing by carefully planning according to crop type and market.

The optimum harvesting stage depends not only on climate and distance to market but also on the specific crop variety and its growing conditions. When distant markets are being investigated, experiments should be carried out to find the best maturity to harvest fruits. Send samples at different degrees of ripeness and assess which gives the best results. It may be necessary to call in expert assistance to identify whether long-term crop storage could significantly improve farmer incomes.[99]

- A simple colour and size guide ("maturity index") can help pickers harvest produce at the correct stage of development; this is the most important factor that determines postharvest life and final quality such as appearance, texture, flavour and nutritive value of fruits and vegetables.

- For many horticultural crops, if harvested all at once there are sure to be many items that are either under-mature or over-mature.

- Consider **harvesting earlier**, when vegetables may be more delicate and valuable; **harvesting later** when fruits are at a riper, more flavourful stage; or **harvesting more often** (taking advantage of multiple harvests to gather produce at its optimum stage of maturity). All these options can lead to higher profits due to produce reaching a higher-quality or niche market.[100] Of course, the distance to market will also influence the most favourable stage to harvest at.

- For climacteric fruits (those that continue to ripen after being picked) such as tomato, banana and mango, harvesting at the mature green stage, instead of

99 Dixie, G. (2015) Horticultural Marketing. FAO, Rome.

100 Kitinoja and Kader (2015) Small scale postharvest handling practices: a manual for horticultural crops (5th edition). Postharvest Horticulture Series no. 8E. University of California, Davis.

the ripe red stage, is preferable as this gives more time to prepare the fruit for the market whilst also reducing incidence of mechanical injuries during harvesting.[101]

- For non-climacteric fruits (fruits that do not ripen after harvest) farmers should not harvest fruit crops too early, when they are under-ripe and have not yet developed their full flavour. Some examples include citrus, grapes, cherries, raspberries, strawberries and cashews.

- Some vegetables, if allowed to grow large, will be too fibrous or full of seeds for good eating quality.

- Similarly, vegetables may be harvested over a wide range of physiological stages, depending upon which part of the plant is used as food.[102]

101 Arah, I. K., Kumah, E. K., Anku, E. K., and Amaglo H. (2015) An overview of post-harvest losses in tomato production in Africa: causes and possible prevention strategies. Journal of Biology, Agriculture and Healthcare 5 (16) 78–88.

102 El-Ramady, H., Domokos-Szabolcsy, E., Abdalla, N., Taha, H., and Fári, M. (2015) Postharvest Management of Fruits and Vegetables Storage. In Sustainable Agriculture Reviews (2015) Lichtfouse, E. (Ed.) Springer International Publishing Vol 15, pp. 66-152.

Box 3. How to avoid waste by adding value[103]

Remember that excess produce and fruits and vegetables that are not perfect in their appearance should not be seen as "waste". Instead, alternative market opportunities should be sought or created, which will add value to the horticulture industry and make it possible for growers to earn a return on over-supplied or blemished produce that would otherwise goes to waste.

Case study: Drying produce

Dryers for Africa specialises in the design and manufacture of agricultural processing equipment. The company has for the last decade been designing and building dryers and processing equipment for commercial and small-scale emerging farmers. Their 'low technology' systems minimise the need for highly skilled engineers and electricians. A variety of heating sources – electricity, gas, coal or biomas fuel – can be used, depending on local availability and cost. The company can customise a system to each client's specific needs, climate and work environment.

"Farm produce that is normally excessive for local use or unacceptable in terms of retail quality would normally go to waste, or sold for little return. Processing by drying and/or juicing increases the value of this raw material. It also improves the shelf life, thus allowing you a longer marketing period for your product. Processing creates employment opportunities and development of specialised skills, thereby adding value to individuals within a community".

1.3. Careless handling of produce

Horticultural produce is by its very nature delicate. Therefore it is imperative that good training is given to all personnel handling the produce during and after harvest. According to Kitinojer and Kader:[103]

- **Pickers should be trained to empty their picking bags and/or baskets with care:** never dumping or throwing produce into field containers. If harvesters pick directly into large bulk bins, produce can be protected from bruising by the use of a de-accelerating chute fashioned from canvas. Vented, stackable field containers should be kept clean and smooth.

103 Kitinoja and Kader (2015) Small scale postharvest handling practices: a manual for horticultural crops (5th edition). Postharvest Horticulture Series no. 8E. University of California, Davis.

- **Workers should be trained in correct sanitation and food safety procedures:** Cleaning of hands with an eco friendly detergent is preferable to avoid creating new waste streams through the use of gloves. In such a case, the waste water should be treated before it is discarded into the environment. However, in cases where gloves are needed as PPE, then these should be of good quality, so that they can be washed and reused by workers.

- **Rough handling during preparation for market will increase bruising and mechanical damage and limit the benefits of cooling:** Roads between the field and the packinghouse should be free from large bumps and holes.

- **Any practice that reduces the number of times the produce is handled will help reduce losses.** Field packing (selection, sorting, trimming and packaging of produce at the time of harvest) can greatly reduce the number of handling steps the produce must undergo before marketing.

1.4. Lack of storage or poor storage conditions

Poor storage of horticultural produce contributes to high rates of post-harvest losses. However, there are a number of simple innovations that can drastically reduce losses as long as farmers can access and properly use them; Zero Energy Cooling Chambers (ZECCs), solar-powered cold storage boxes, and charcoal coolers, among others, are ways to extend produce freshness. For perishable crops such as fruits and vegetables, a properly managed temperature-controlled supply chain can buy time before food is lost. These solutions can reduce post-harvest losses and efficiently link farmers to regional and global markets.[104]

104 Rockefeller Foundation newsletter, February 27 2017. Agriculture is Cool! Available at www.rockefellerfoundation.org/blog/agriculture-is-cool/.

Produce can be stored for both short-term and long-term purposes. Short-term storage is mainly used to provide flexibility in marketing (e.g. when awaiting transport), or because buyers are not immediately available. Most horticultural crops are perishable and can only be stored for a few days. Only rarely is it worthwhile storing perishable crops to await higher prices, as storage will reduce quality and shelf life whilst adding to costs.

Often, the most successful stores are located in urban areas because:

- produce can be released rapidly onto the market when prices increase;
- refrigerated facilities in urban areas can also be used for a variety of products (e.g. apples in the winter, citrus in the summer, butter and other milk products).

In addition, air and sea ports tend to have cold storage facilities located on-site to aid in effective cool chain management.

Refrigerated storage is expensive and requires an adequate demand for storage, good management and a reliable supply of electricity. It is often necessary, particularly for produce destined for export, which requires an increased shelf life to maintain its high quality. For more information on good energy management, see ColeACP Manual on Energy Management.

Shelf life can, however, be extended without investment in expensive storage equipment. The first priorities should be **selecting high-quality produce** (i.e. free of bruises, pest and disease damage), **maintaining a high humidity** (for example by storing in Zero Energy Cool Chambers, as per below) and **keeping produce in the shade.**

Case study: Zero Energy Cool Chambers (ZECC) in Zambia[105]

"Evaporative coolers can extend the shelf life of many horticulture crops by as much as 50-200%, helping producers avoid spoilage by keeping crops at 10 to 15°C below room temperature without using electricity.

Even just a few days of additional shelf life for perishables can mean a lot in terms of the price farmers capture for their crops. An example of a low-cost evaporative cooling option, ZECCs can store multiple crops at one time, and help farmers maintain water weight in their crops, reducing wilting and quality diminishment that hastens crops' decay and reduces marketability.

ZECC units can be easily constructed with local materials: bricks, sand, water, and branches/leaves. An outer brick wall, soaked in water, houses an inner brick wall with wet sand between the two walls, and the top covered with branches/leaves. ZECCs can be constructed in a variety of sizes (100 kg to 1 metric ton), serving the needs of individual farmers, farmer associations, packinghouses, and others." (Source: Rockefeller Foundation, 2014). ZECCs maintain a cool temperature and high humidity and may require 25 – 50 litres water per day to operate.

Figure 15: An example of a ZECC design
Source: UCCE[106]

105 Reducing global food waste and spoilage (2014) A Rockefeller Foundation Initiative. Assessing resources needed and available to reduce post harvest food loss in Africa. The Rockefeller Foundation and Global Knowledge Initiative. http://postharvest.org/Rockefeller%20Foundation%20Food%20Waste%20and%20Spoilage%20initiative%20Resource%20Assessment_GKI.pdf.

106 http://ucce.ucdavis.edu/files/datastore/234-2143.pdf.

Case study: Solar powered cold storage boxes: ColdHubs

The ColdHub concept was developed to help the 470 million farmers and retailers in developing countries (Rockefeller Foundation; Food Waste and Spoilage Initiative 2014), who do not have access to reliable cold storage.[107]

ColdHubs are modular, solar-powered walk-in cold rooms that provide 24/7 off-grid storage and preservation of perishable foods. They are installed in markets and farms within the reach of farmers and retailers. Fresh produce is placed in clean plastic crates (provided) and these crates are stacked inside the cold room. The cold room temperature of 5°C extends the freshness of fruits, vegetables and other perishable food to about 21 days instead of 2 days without refrigeration, reducing postharvest losses by up to 80%. Farmers pay a daily flat fee of around US$0.50 for each crate of food they store, and only pay when they have produce to store.[108]

The solar powered walk-in cold room is made of 120mm insulating cold room panels to retain cold. Energy from solar panels mounted on the rooftop of the cold room is stored in high capacity batteries, which in turn feed the refrigerating unit. The exterior dimensions are 10' x 10' x 7'. The stainless floor is made with 0.8 – 1mm aluminium. Each Hub may hold 2–3 tons of perishable food arranged in at least 150 units of 30kg plastic crates stacked on the floor. ColdHubs provide autonomous refrigeration 24/7 without grid connection.

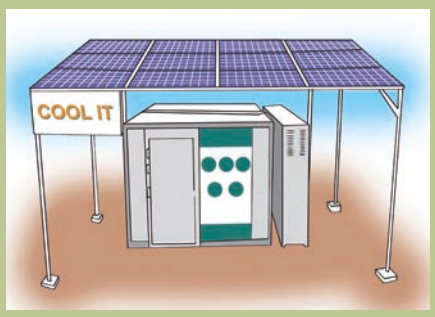


Photo: A ColdHub solar-powered store in Nigeria[109]

107 www.coldhubs.com Accessed 25th May 2017.

108 www.startup.info/coldhubs/.

109 www.coldhubs.com/#home-section.

1.5. Transportation infrastructure losses

Losses directly attributed to transport conditions can be high. The goal of every person concerned with transport should be that the produce be kept in the best possible condition during transport and that the haulage of produce be quick and efficient. To this end, produce should be properly packaged and properly loaded on a suitable vehicle.

1.5.1 The problems[110]

a) Mechanical damage from the following:

- Careless handling of packed produce during loading and unloading;
- Vibration (shaking) of the vehicle, especially on bad roads;
- Fast driving and poor condition of the vehicle;
- Poor stowage, which allows packages in transit to sway; the stow may collapse;
- Packages stacked too high; the movement of produce within a package increases in relation to its height in the stack;
- Co-loading of the vehicle with hazardous or odorous products, making the fresh produce unsellable due to contamination

b) Overheating of produce leading to rapid decay, from the following:

- The use of closed vehicles without ventilation;
- Close-stow stacking patterns blocking the movement of air between and through packages, thus hindering the dispersal of heat;
- The lack of adequate ventilation of the packages themselves;
- Exposure of the packages to the sun while awaiting transport or while trucks are queuing to unload at their destination.

110 FAO (1989) Prevention of post-harvest food losses fruits, vegetables and root crops: a training manual. Rome. Available at: www.fao.org/docrep/t0073e/T0073E04.htm

1.5.2. The solutions

a) Selection of vehicle

- Closed vehicles without refrigeration should not be used to carry fresh produce except on very short journeys, such as local deliveries from farmers or wholesalers to nearby retailers;

- Open-sided or half-boarded trucks can be fitted with a roof on a frame. The open sides can be fitted with canvas curtains which can be rolled up or moved aside in sections to allow loading or unloading at any point around the vehicle. Such curtains can protect the produce from the elements but still allow for ventilation. Where pilfering is a problem, the sides and rear of the truck must be enclosed in wire mesh;

- A second, white-painted roof can be fixed as a radiation shield 8 or 10 cm above the main roof; this will reflect the sun's heat and help to keep produce cool;

- For the ventilation of long-distance vehicles, more elaborate air intakes can be fitted in conjunction with louvres, to ensure a positive air flow through the load;

- Refrigerated trucks or road, rail or sea containers may be used for long journeys, but the cost of such transport may make it uneconomical for small-scale operations.

b) Handling and stowage practices

- The size and design of packages should give adequate levels of ventilation of contents with the minimum of wasted space, and the packages should be strong enough to protect the contents;

- Loading and unloading of vehicles should be properly supervised to prevent careless handling of packages;

- Packages should not be stacked higher than the maximum recommended by the maker, otherwise the bottom layers may collapse under the weight of those above;

- Packed produce should be protected from sun and rain at all times including during loading and unloading;

- Packages should be loaded on pieces of lumber or slatted racks on the beds of vehicles, or on pallets in order to allow the circulation of air around stacks during transport. In addition, packages should be loaded so that they are away from the side walls and the floor of the transport vehicle in order to minimize the conduction of heat from the outside environment.

- There should always be a void between the last stack of produce and the back of the transport vehicle. The load should be braced to prevent shifting against the rear door during transit. If the load shifts, it can block air circulation, and fallen cartons can present great danger to workers who open the door at a destination market. A simple wooden brace can be constructed and installed to prevent damage during transport.

- Vehicles can be padded or lined with a thick layer of straw. Woven mats or sacks can be used in the beds of small vehicles. Other loads should not be placed on top of the bulk commodity.

- If the load is to be distributed to several locations, packages should be loaded in reverse order to that in which they will be unloaded, i.e. last on, first off; at the same time the load should be distributed evenly on the vehicle.

- During transportation, the produce should be immobilised by proper packaging and stacking to avoid excessive movement or vibration. Vibration and impact during transportation as a result of undulations on roads are one of the major causes of postharvest losses to most fruits and vegetables.[111]

- Drivers of vehicles used for shipping produce must be trained in how to load and handle their cargoes.

- Travelling during the night and early morning can reduce the heat load on a vehicle that is transporting produce.

- Often the large containers used for cut flower packaging must be hand-stacked when loaded into a transport vehicle. The best loading pattern for cut flowers is known as the pigeon hole pattern, where boxes are stacked in alternating solid and open layers, and channels are left down both side walls. This pattern provides channels for air circulation lengthwise through the load, and allows every box to be in direct contact with refrigerated air.

111 Arah et al (2016) Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. Advances in Agriculture.
Available at www.hindawi.com/journals/aag/2016/6436945/#B23.

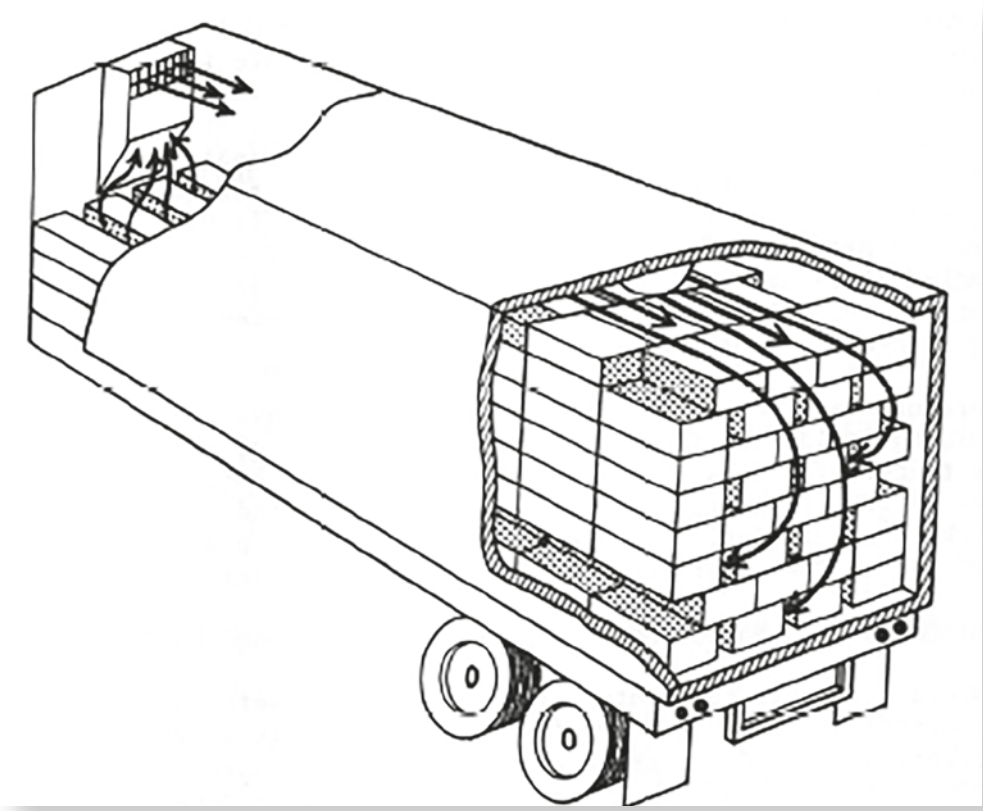


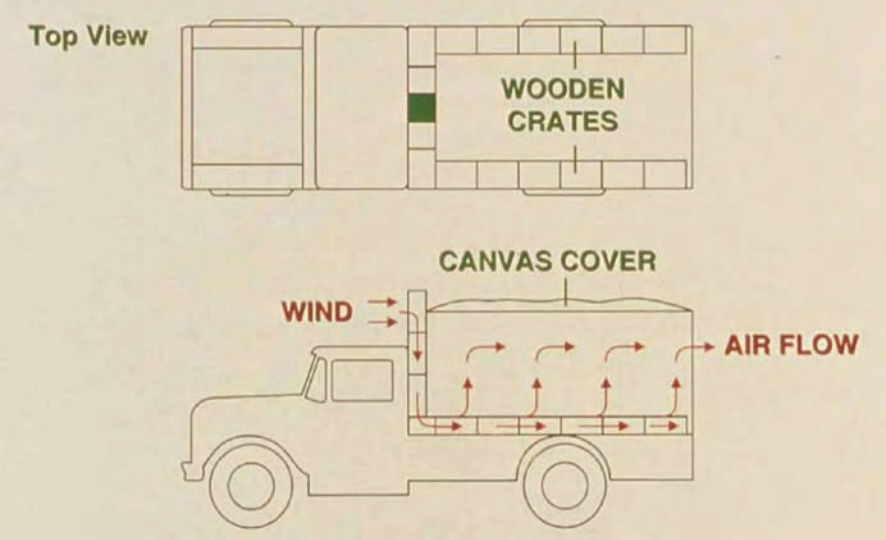
Figure 16: The pigeon hole stacking pattern for cut flowers.
Source: UC Davies[112]

This diagram shows how the pattern allows air to circulate from the rear to the front of the trailer through lengthwise channels in alternate layers of the load and along the side wall in the other layers. The top layer is staggered every other stack. Next to the front bulkhead, a head stack is required to allow air to return (move upward) to the refrigeration unit, unless the bulkhead has built-in space.

112 UC Davies (1979) Handling, precooling and temperature management of cut flower crops for truck transportation. http://ucce.ucdavis.edu/files/datastore/234-1052.PDF.

Box 4. A simple truck ventilation system[113]

A truck-ventilating device can be constructed for an open vehicle by covering the load loosely with canvas and fashioning a wind catcher from sheet metal. The scoop should be mounted at the front of the bed and should reach somewhat higher than the height of the cab. Note that high transportation speeds and/or long distance transport run the risk of causing excess drying of the crop.



This ventilating system was designed for hauling bulk loads of fresh fava beans in Iran. The wind catcher and ducts were constructed using wooden crates. After removing their end panels the crates were wired together into the pattern shown below. Air flows upward through the load during transport, helping to keep the produce from overheating. This system has also been used in pick-up trucks, and for hauling bulk greens and green beans. Best results are obtained when transporting during the early morning hours, before sunrise.

1.6. Short-notice order cancellations

When an order is cancelled or reduced at the last minute, exporters and farmers are often left with no other markets for their produce.[114] Some larger exporters are able to send cancelled orders to other customers at short notice, but more commonly the produce is either dumped, or returned to the farmer. The severity of these losses range from slight reductions in forecast orders to entire order cancellations.

113 Kitinoja and Kader (2015) Small scale postharvest handling practices: a manual for horticultural crops (5th edition). Postharvest Horticulture Series no. 8E. University of California, Davis.

114 Feedback (2015) Food waste in Kenya: Uncovering food waste in the horticultural export supply chain. Available at www.feedbackglobal.org/wp-content/uploads/2015/07/Food-Waste-in-Kenya_report-by-Feedback.pdf.

Order cancellations can occur before or after the produce has been harvested, sometimes even hours before it is due to be exported after being graded and packed. Because horticultural produce has very short shelf life, the farmer has only a short period of time before the product becomes unsellable and therefore ends up as waste.[115]

Often produce is not saleable on the local market even if it is still fresh, as it does not appeal to the local cultural palette. Ultimately, this has serious implications for smallholder farmers, who are not paid for cancelled orders even when the produce has already been harvested, leading to considerable financial loss.

How can this problem be avoided?

Research by Feedback (2015)[116] found that where farms and exporters were vertically integrated with European importers, order cancellations did not arise due to the nature of effective communications within the business supply chain. Increased transparency throughout the supply chain would incentivise accurate forecasting on behalf of these businesses, and would ensure that importers were not able to cancel orders at the last minute in favour of cheaper produce from suppliers in other regions of the world.

Feedback (2015) therefore make the following recommendations:

- Improving forecasting methods and models to increase accuracy with the direct input of their suppliers;
- Changing the structure of their supply chains, for example by creating a more direct relationship with primary farmers;
- Guaranteeing the purchase of a certain percentage of their suppliers crop or fully compensating their suppliers for last minute order adjustments;
- Helping their farmers access local or secondary markets for their excess produce either by relationship brokering or by investing in relatively low cost initiatives that can extend the shelf life and add value to the rejected produce by repurposing it;
- Development of local market for non traditional export products;
- Development of domestic value addition processing industry, such as mango and banana drying units; this type of processing not only reduces waste but also generates greater incomes for people involved in the industry, without the need for significant financial investment;

115 Consumers International (2012) The relationship between supermarkets and suppliers: What are the implications for consumers? Available at www.consumersinternational.org/media/1035301/ consumer%20 detriment%20briefing%20paper%20sept2012.pdf.

116 Feedback (2015) Food waste in Kenya: Uncovering food waste in the horticultural export supply chain. Available at www.feedbackglobal.org/wp-content/uploads/2015/07/Food-Waste-in-Kenya_report-by-Feedback.pdf.

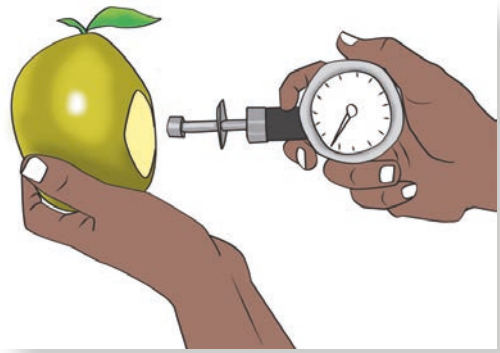
- Creation of collection and redistribution points to ensure that instead of going to waste, unsold produce can be delivered to schools, children's homes, street children and medical centres;

- Joining farmers together in cooperatives or professional associations can help to greatly reduce food losses by increasing their understanding of the market, enabling more efficient planning, enabling economies of scale and improving their ability to market what they produce.[117]

In addition, establishing a trusting relationship between the farmer and buyer can help with negotiating signed contracts, including advance payments, agreed price and guaranteed purchase.

1.7. Losses due to non compliance

Many customers have strict rules on the quality, cosmetic appearance and sizing of fresh produce. This is particularly the case for product destined for EU retailers. It is therefore important to train staff in careful handling and selection of produce to ensure that whole batch loads do not get rejected or, worse still, supply contracts are not cancelled all together.



Checking quality of fruit with a PH meter

Furthermore, growers should aim to have several markets available for their produce so that if some is rejected by one customer purely for cosmetic reasons, it may be sent elsewhere for sale as a 'lower grade'.

To reduce the chance of produce rejection, careful post-harvest (PH) sorting and handling must be assured.

Much focus of this chapter has already been given to harvest practices, so here we focus on the stages taking place at the packhouse or post-harvest sorting facility.

a) **Dumping:** The first step of PH handling common to all fruits is known as dumping. It should be done gently either using water or dry dumping. Wet dumping can be done by immersing the produce in water. It reduces mechanical injury, bruising,

117 FAO (2017) Available at www.fao.org/news/story/en/item/196377/icode/.

abrasions on the fruits, since water is more gentle on produce. Dry dumping is done by soft brushes fitted on the sloped ramp or moving conveyor belts. It helps in removing dust and dirt from produce.

b) **Pre-sorting:** This is done to remove injured, decayed, misshapen produce. Removing decaying produce is especially important, to limit the spread of infection to other healthy produce during handling.

c) **Washing and cleaning:** Washing with chlorine solution (100–150ppm) can also be used to control the build up of decay-causing microorganisms during pack house operations. For best results, the pH of wash solution should be between 6.5 and 7.5

d) **Sorting:** This is an important step to ensure that fresh produce arrives to the customer at the standard expected. For example, produce intended for local market will have less strict sizing conditions than produce intended for supermarkets.

1.10. Packing and packaging

Good packaging design enhances the attractiveness of produce, enables it to be handled and marketed in convenient units, and helps to prevent mechanical damage. It is important to minimize mechanical damage by avoiding drops, rough handling and bruising during the different steps of pack house operations.[118]

Secondly **the pack house operations should be carried out in shaded area**. Shade can be created using locally available materials such as shade cloth, woven mats, plastic tarps or a canvas sheet hung from temporary poles. Shade alone can reduce air temperatures surrounding the produce by 8–17 °C.

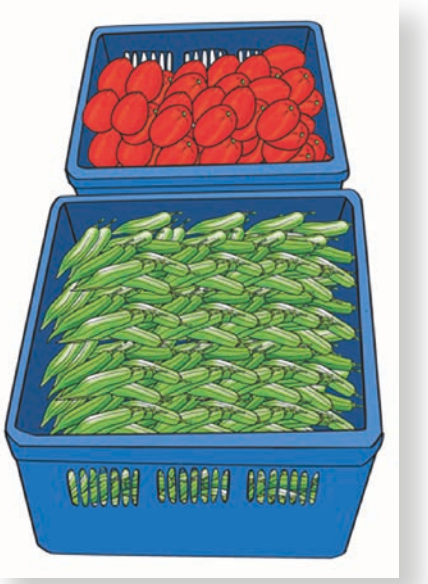
118 El-Ramady, H., Domokos-Szabolcsy, E., Abdalla, N., Taha, H., and Fári, M. (2015) Postharvest Management of Fruits and Vegetables Storage. In Sustainable Agriculture Reviews (2015) Lichtfouse, E. (Ed.) Springer International Publishing Vol 15, pp. 66-152.

Packaging materials

Low quality fiberboard cartons can collapse during high humidity cool storage

Packaging can be the single most expensive cost, particularly with non-returnable containers made of wood or cardboard. The benefits of packaging must clearly justify the investment. Traders usually aim to minimize costs and are reluctant to invest in packaging unless the financial benefits are clear. As a result, the financial burden often rests with the farmer. It is therefore important for farmers to have access to effective, affordable and sustainable packaging options; as packaging also contributes to the waste stream, recommendations should be made for **returnable and reusable** plastic containers, or **decomposable packaging** materials such as paper and card, which can be added to compost heaps.

Good packaging design can help to reduce mechanical damage caused to fresh produce: cuts, compression bruises, impact damage and vibration rubbing.



- Cuts. Care in harvesting and handling will help eliminate cuts and wounds. Lining of packaging with shredded clean paper (e.g. shredded office documents) can also prevent damage to the contents.

- Compression bruises. These can be reduced by using containers that are strong enough to withstand multiple stacking. The packaging materials need to be particularly strong at the vertical corners. The packaging should also be shallow enough to prevent the bottom layers of produce from being damaged by the weight of produce above. Cartons must not be overfilled or damage will be caused by the full weight of the pile of produce pushing down on the top layer of fruit or vegetables, causing the weight to be transmitted to the lower layers.

- Impact damage. Shocks in transport or dropping of containers can result in this kind of damage. Dropping may occur either because a package is small enough to be thrown or because it is too big to be easily handled. A packing unit should not exceed 50 kg as this is the maximum weight that can be easily handled. Package size specifications usually depend on the customers' requirements, although in many countries the supply of good packaging materials is limited and buyers may have to accept what is available.

- Vibration rubbing. This kind of damage generally occurs during transport. It can be significantly reduced by preventing the produce from moving within the packaging while, at the same time, ensuring that fruits or vegetables are not forced together. Fruits can be prevented from rubbing against one another by the use of cellular trays, individual wraps or cushioning pads. An example is the use of paper and straw to separate layers of apples. An alternative approach is for the container to be gently shaken, in order to settle the produce, with the space created then being filled.

Produce may be packed in sturdy returnable plastic crates for transport from the farm to central packing facility, in order to protect it from transport-related damage during transit. Once at the central facility, produce can then be re-packaged in lightweight and recyclable components ready for export. For example, fruits packed in recyclable clear plastic cartons/punnets, which are then placed inside cardboard outers. Clear plastic enables easy inspection and is a suitable option when the plastic used is recyclable.

Case study: Returnable Plastic Crates (RPCs)[119]

According to the Postharvest Education Foundation, improved postharvest containers are one of the more practical and cost effective changes that can made on an incremental basis by smallholder food producers, handlers and marketers. The rigid nature of 'Returnable Plastic Crates' (RPCs) provides protection for fresh produce all the way to the export packhouse, including over rough, poor road surfaces, thereby reducing damage and resulting losses of fresh produce.

Furthermore, the ability to re-use RPCs many times reduces the creation of waste from packaging containers; one recent study, reviewing the use of RPCs for 10 fresh produce commodities, concluded that RPCs required 39 percent less total energy, **created 95 percent less solid waste**, and generated 29 percent less total greenhouse gas emissions than corrugated display ready containers (Source: PackagingRevolution.net white paper, 2012).

Use of RPCs in many countries for handling and storage of many types of fruits and vegetables can be highly cost effective, since overall RPC costs are often lower than the savings that can result from reduced food losses; RPCs are ideal for handling fresh horticultural produce and other food since they were specifically designed for maintaining the quality of the produce (Vigneault *et al.*, 2009).

RPCs can be used to replace poor quality containers such as cloth bundles, jute or polypropylene sacks, woven baskets, and flimsy low quality crates made of thin plastic or Styrofoam. They can also replace expensive single use fiberboard cartons, as well as locally made crates that are constructed from rough wooden planks or palm ribs; many of these packages use natural resources to manufacture and end up either being transported to landfills or decomposing underfoot as debris in marketplaces after one or two uses.

Photo: Poor quality packaging; enlarged sacks for cabbages in Ghana and mixed containers in Cape Verde
Source: The Postharvest Education Foundation[120]

119 The Postharvest Education Foundation (PEF) (2013) PEF White Paper No. 13-01: Returnable Plastic Crate (RPC) systems can reduce postharvest losses and improve earnings for fresh produce operations. PEF White Paper No. 13-01 based upon a Desk Study by Dr. Lisa Kitinoja. Available at http://postharvest.org/RPCs%20PEF%202013%20White%20paper%2013-01%20pdf%20final.pdf.

120 *Ibid.*

Sri Jayewardenepura University – Institute of Postharvest Technology in Sri Lanka, introduced plastic crates to farmers, collectors and wholesale traders for transportation of fruits and vegetables under the "Fresh Produce Chain" concept that was initiated in 2001. The crates cost about US$5.00 and the government provides a 50% subsidy to the buyers.

An exchange system has been developed wherein the farmer or trader who delivers a full crate of produce to the buyer gets an empty crate in return. In a study on RPC use conducted in Sri Lanka, the quality and safety of vegetables reaching the consumer were improved appreciably. In the case of mangoes and avocados, the use of plastic crates for handling and transportation resulted in a reduction of losses from 30% to 6% (Fernando, 2006). However in most export chains single use cardboard boxes are used from the packhouse onwards, to achieve a certain weight eg. citrus boxes contain roughly 12kg of products and keep perishables dry.

Photo: Strong RPCs; Stackable RPCs in use from farm to market in Sri Lankac; RPCs in cool storage in a Zero Energy Cool Chamber in India
Source: The Postharvest Education Foundation[121]

121 Photo credits: a: Adel A Kader (2009); b: Lizanne Wheeler (2008); c: PEF (2009); d: Amity University (2009). All sourced from The Postharvest Education Foundation (PEF) (2013) available at http://postharvest.org/RPCs%20PEF%202013%20White%20paper%2013-01%20pdf%20final.pdf.

2. ESTABLISHING A COMPANY PROGRAMME AROUND WASTE

2.1. Reducing post-harvest losses (PHL)

This chapter has so far focussed on the causes of PHL in horticulture, and solutions to help farmers and other actors along the supply chain to achieve PHL reduction. In order to implement these solutions, an effective management plan needs to be developed. This will ensure that waste streams are correctly identified and measured, appropriate actions are put into place, and progress is monitored.

The first step in developing any waste management plan or programme is to determine the **baseline**: where are we currently? What waste streams are we producing and how much? Where is the waste currently being taken and for what end-use? From there, a **strategy** for waste management should be developed, based on ideas and inputs from a number of relevant stakeholders in the business or supply chain.

Finally, **implementation** of the strategy should take place; this includes carrying out the waste management activities and also monitoring them for continuous improvement over the long-term.

2.1.1. The step-by-step approach to developing a 'Post-Harvest Loss Management Plan'

Step A **- CREATE A BASELINE**

1. **Identify waste streams**
   a. Plant material – saleable
   b. Plant material – compostable
   c. Plant material – for animal feed
   d. Plant material – for energy recovery
   e. Non-plant reusable materials – potential use opportunities
   f. Non-plant recyclable materials – sorting categories
   g. Landfill materials

2. **Estimate the volume of each waste stream**

3. **Identify the causes of each of these waste streams**
   a. Cross check waste causes with volumes – where are the greatest losses occurring?

Step B **- DEVEVELOP A STRATEGY**

4. **Identify options to reduce each waste stream –** start with the potential for biggest gains
5. **Identify options to re-purpose (re-use) each waste stream, for example making compost or liquid fertiliser for use on-farm**
6. **Identify options to recycle locally**
7. **Identify materials which are only appropriate for landfill or incineration**
   a. Research alternative materials which could replace these over time

Step C **- IMPLEMENT THE PLAN**

8. **Deploy targeted, local solutions.** Numerous cost effective solutions exist to reduce sources of loss identified in the value chain. To be effective, however, they need to match the local context.[122]
9. **Create a monitoring programme including targets for reductions over time.**
10. **Ensure you name those responsible for implementing the plan and roles are clearly defined.**

This type of company waste management programme will enable all employees to better understand the issues in their value chain. Further, by involving all employees from the start, a broad range of issues and ideas will be raised, employees will feel involved and valued and therefore be more likely to understand and implement the programme, ultimately creating a more impactful waste management strategy.

In addition, **collaboration is key**; companies will benefit from connecting with suppliers and other partners along their own value chain to identify and analyse the different causes of food loss and specific opportunities.[123]

A growing number of partnerships are developing that share risk and generate mutual benefit. The type of possible partners ranges widely from suppliers to agriculture extension resources, as well as local governments, civil society, and providers of infrastructure and distribution solutions.

122 BSR (2013) Losses in the Field: An Opportunity Ripe for Harvesting. Available at www.bsr.org/reports/BSR_Upstream_Food_Loss.pdf.

123 BSR (2013) Losses in the Field: An Opportunity Ripe for Harvesting. Available at www.bsr.org/reports/BSR_Upstream_Food_Loss.pdf.

2.2 Diversification initiatives to reduce food loss in the supply chain

Identifying alternative markets for produce, which may otherwise be disregarded as waste is an important step in ensuring a diversified, and therefore more resilient, business.

Traditional processing technologies such as thermal processing (bottling and canning), freezing, dehydration (salting, brining and candying) drying, and fermentation are widely applied in the processing of fruits and vegetables at various levels (artisanal, intermediate and high) and scales (cottage, small, medium and large).

Tropical juices and fruit pulps, canned pineapples, tomato paste and canned and dried mushrooms are examples of fruit and vegetable products produced using traditional processing technologies and which are increasingly entering in international trade.[124] An example of this is the production of tomato paste.

2.3 Tomato Jos – turning waste into paste

Tomatoes are grown on approximately 1.3 million hectares in ACP countries, producing around 20 million tonnes in 2014.[125] However, between the harvest and consumption stages, it is estimated that up to 50% of tomatoes end up as waste in tropical countries.[126] At the same time, tomato paste is a popular cooking component across the tropics.

Nigeria is Africa's most populous country and largest economy, and grows over 1.5 million tons of tomatoes each year. Nigeria is ranked 16th on the global tomato production scale, and accounts for 10.8% of Africa's and 1.2 per cent of total world production of tomatoes.

An alarming 45% of tomatoes harvested in the country is lost due to poor Food Supply Chain (FSC) management and consequently the food safety of the crop.[127] The food lost after harvest is enough to feed an additional 300 million people in a continent where roughly 200 million experience chronic food insecurity. Given that many smallholder farmers live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods.

Unfortunately, the crop is highly perishable and deteriorates a few days after harvest. It is estimated that about 45 % of tomatoes harvested in the country is lost due to poor Food Supply Chain (FSC) management. This is equivalent to an annual loss of 750,000 tonnes and this is partly why the government has to import over 300,000 tons

124 El-Ramady, H., Domokos-Szabolcsy, E., Abdalla, N., Taha, H., and Fári, M. (2015) Postharvest Management of Fruits and Vegetables Storage. In Sustainable Agriculture Reviews (2015) Lichtfouse, E. (Ed.) Springer International Publishing Vol 15, pp. 66-152.

125 FAOSTAT (2017) Data for 2014. See www.fao.org/faostat/en/#data/QC/visualize.

126 Arah *et al* (2016), Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. Advances in Agriculture. Disponible à l'adressewww.hindawi.com/journals/aag/2016/6436945/#B23.

127 www.belvynaglobal.com/tomato-production-in-nigeria-prospects-of-a-bright-future.

of processed tomato paste valued at over USD$360million from as far as China and Singapore.[128]

The government launched the Tomato Working Group Implementation Action Plan 2012 – 2015 to sensitize value chain actors in tomato industry, with a view to developing and boosting the production, processing, marketing and consumption of the commodity.

In 2015, an entrepreneur recognized the business opportunity and set up the $30 million Dangote Tomato Processing Factory, with a daily processing capacity of 1,200 tons of raw produce. This factory could provide a guaranteed market for produce that would otherwise be lost for thousands of farmers.

On a smallholder level a small local initiative was also set up to organise smallholder farmers, called "Tomato Jos".[129] The Tomato Jos dream began in 2008, when Mira Mehta encountered her first tomato market glut in Northern Nigeria. "Farmers had lined the roads with tomatoes in an effort to dry and preserve them, because prices were at an all-time low. The more Mira learned, the stranger the story got. Nigerian farmers produced 65% of the tomatoes grown in West Africa, but paradoxically, it was also the largest importer of tomato paste in the world. It just didn't make any sense – why import all that paste when Nigeria already grew so many tomatoes? This was clearly a huge problem, but it also seemed like a huge opportunity."[130]

Today, Tomato Jos has over 20 employees and works with smallholder farmers to produce tomatoes in using sustainable farming techniques. The tomatoes are then purchased and processed into paste, thereby supplying the market, supporting the national economy and reducing the high levels of tomato waste that occur when tomatoes are sent to the local market for fresh consumption.

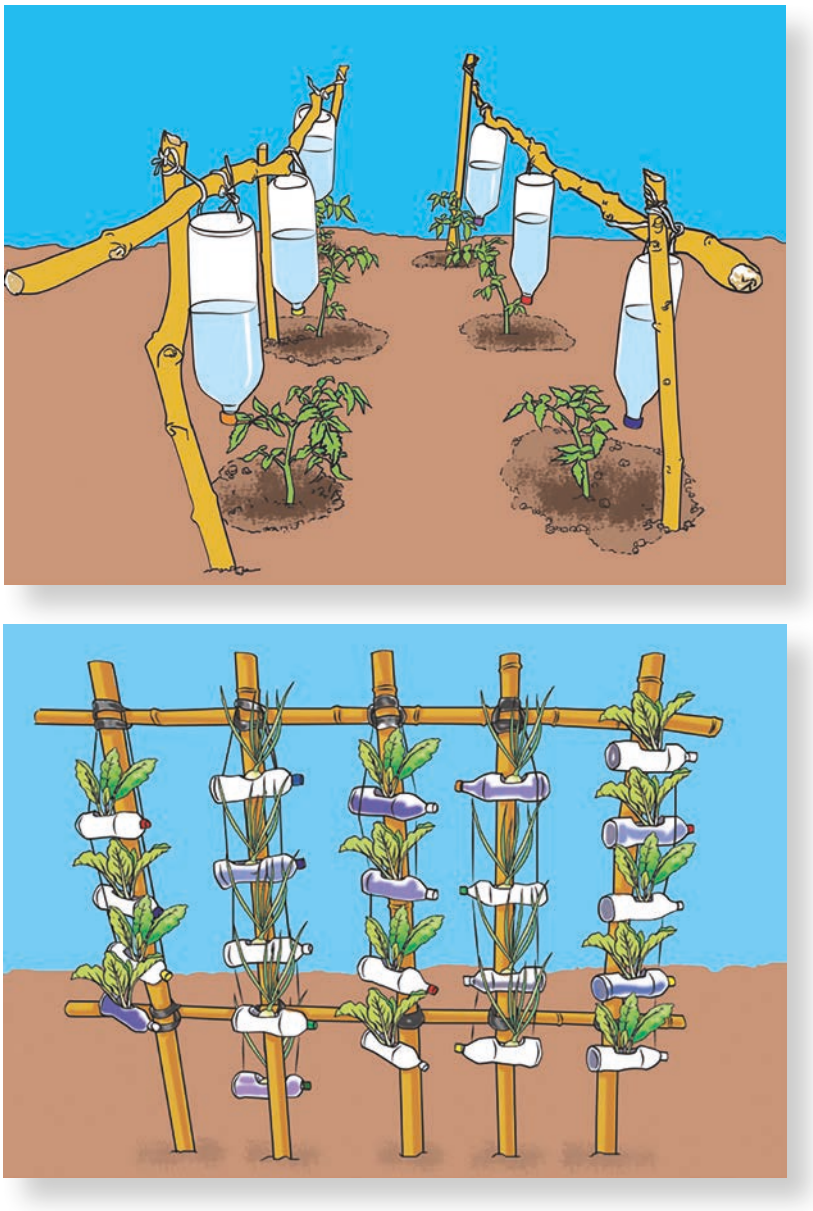
128 *Ibid.*

129 www.changemakers.com/sustliving2014/entries/tomato-jos.

130 www.tomatojos.net/the-team/.

2.4. Reducing waste production in other departments

Aside from the fresh produce itself, there are a number of other waste streams that occur during horticultural production and postharvest. Their options for 'reduce, reuse or recycle' differ considerably. To manage these, businesses need to 'think outside the box'; could office paper waste be reused as animal bedding? Could plastic bottles be used as planters or for simple drip irrigation? This section explores other areas of the horticulture industry where waste can be reduced.



An example of plastic reuse on the farm, hydroponic systems.

2.5 Personal Protective Equipment (PPE): reusable versus disposable

Personal protective equipment (PPE) is essential for ensuring high standards of hygiene at fresh produce packing and processing sites.

Items commonly used include gloves, hairnets, aprons and shoe covers. While many of these will be viewed as 'single use' items, due to the need for them to remain sterile, it is possible to re-use these items as long as they are stored in a safe, sterile environment such as within the processing facility itself.

Remember that investing in higher-quality items that have a longer lifespan will reduce waste and, whilst they may be more expensive to purchase, should last longer, potentially saving money over the long term. For example, instead of poor-quality, flimsy masks, companies may purchase good quality, strong masks that one can replace the filters on.

As mentioned previously, items such as knives can also be sanitized and reused. When they become blunt, a knife sharpener should be used to prolong their life and maintain high quality cuts; a sharper knife will make cutting easier, quicker and can make a big difference in the quality of the final product.

2.6. Maintaining instead of replacing equipment

For longer-life equipment such as heavy machinery, items should be regularly maintained to ensure that they continue to work at optimal levels. All maintenance work should be carried out by a trained mechanic or technician to ensure that it is done so in a safe manner, and that any repairs are carried out correctly.

A maintenance logbook should be kept, to record all repairs and service checks carried out on each piece of machinery. The logbook should be kept up-to-date.

Maximise tractor tyre life by using the correct machinery for the job and maintaining the vehicle properly to reduce wear. Keep tyre pressures to recommended levels to ensure even wear. Under-pressured tyres can lead to lower fuel efficiency and can be dangerous.[131]

Other long-life equipment such as wooden pallets can be repaired to ensure a longer life, thereby reducing waste and purchase costs.

When equipment such as light bulbs needs replacing, lower-energy longer-life options such as LED light bulbs can be sought; some modern LED light bulbs are estimated to have a lifespan as long as 25 years.

Whilst they may be more expensive to purchase, their low energy consumption and long lifespan will result in long-term cost savings in addition to much lower waste.

2.7. Recovering materials at the 'End-of-Life'

The fate of equipment and machinery at the end of its designed-for life should be specific to each material: for example, plastic irrigation piping may be recyclable and therefore be sent to the local recycling facility; plastic drinks bottles can be re-used as seed planters or drip irrigation devices; rubber tyres can be used for weighing down plastic sheeting that covers animal silage feed.

They can also be made into childrens' swings, planters, bicycle racks and even steps (shown in the photos below) although care must be taken to ensure that they do not collect stagnant rainwater in their rim and thus provide a breeding ground for mosquitoes.

Unwanted rubber items may be able to be sent to a central recycling facility. Importantly, rubber and plastic items should not be burned due to the release of toxic chemicals into the environment.

131 http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=60610&id=60746.

Photos: New uses for old tyres: to create steps and a bicycle rack
Source: Recyclecart[132]

Certain co-products of spent machinery such as oils and lubricants cannot simply be recovered or disposed of into the environment as they are classified as hazardous waste due to their toxicity as well as their fire hazard. Instead, they should be stored separately and returned to a local recycling point (this may be the same place where they were purchased), where they can be refined for re-use. When you next purchase oils or lubricants, enquire at the point of sale where the nearest facility for oil recycling is; some facilities also offer collection for a fee.

2.8. Maintenance of facilities and treatment of water

In addition to the material waste streams discussed in this chapter, waste is produced due to site cleaning; for example, water used for washing produce and equipment and cleaning products such as caustic agents. This is an important step to ensure high levels of food safety. It must be carried out carefully, as cleaning chemicals can be harmful to both people and the environment.

Minimal amounts of water and chemicals should be used, to ensure minimum impact on the environment and to ensure that costs are kept relatively low.

As water supply charges and effluent treatment charges will rise with time, it makes environmental and economic sense to reduce water consumption at processing sites. Further, water recycling can be implemented whereby cleaning water is continuously collected and re-used throughout the day, then discharged to a sedimentation lagoon at the end of each day. The facility is then cleaned down with fresh water at the end of the day.

132 Source: www.recyclart.org/2009/02/bikestand-made-of-tires/.

Here are a few tips:

- For cleaning products, all chemicals should be labelled with their correct application rates and methods, and the correct rates should be used; avoid 'using up the last few drops' in a container just to empty it.
- Switch off unattended hoses.
- Fix faulty water valves, taps and hoses.
- Fix trigger nozzles to hoses.
- Use spray nozzles to clean equipment.
- Keep spray nozzles free from dirt and limescale by cleaning regularly.
- Sweep up solid waste rather than hosing it away with water.

2.9. Reducing waste in the office

Office consumables such as printing paper and toiletries, as well as energy, can often be reduced and recycled.

Implementing some basic procedures and creating a staff ethos that supports these procedures is important here. For example, staff should ask "do we need to print this?" before printing documents.

Here are a few tips:

- Think about whether printing a document is necessary.
- Print on both sides.
- Shred unwanted paper documents and use the shredded material as packaging material.
- Put paper recycling bins in strategic places in offices, such as next to copiers and printers.
- Print in draft mode, in black and white, to reduce the use of ink.
- Buy recycled paper.
- Distribute information to employees by email instead of paper if employees have regular access to email accounts.
- Turn off all office equipment and heating/air conditioning at weekends and over public holidays.
- Install windows and skylights to take advantage of natural lighting and reduce the need for electricity.
- Select office machinery such as computers and copiers based on quality and low-energy rating.

- Install low-flow faucets and toilets.
- Install air dryers in bathrooms to avoid the need for paper towels.
- Provide reusable cups and drinking water facilities for employees to avoid the need for plastic bottles.

2.10. Developing a Waste Reduction and Purchasing Policy (WRAP)

Purchasing or inbound logistics departments can take a number of steps to foster waste prevention. This list of ideas was approved by professional procurement officers and is intended to help you jump-start your waste prevention efforts and save money too. Review your existing purchasing policies to assure they do not inhibit or exclude buying goods with recycled content or products designed to be reused or recycled. .

Try to procure products that reduce waste. These include products that:

- Are designed to last a long time (utilize long warranties and repair service options when appropriate);
- Have replaceable parts so they are easy to repair;
- Can be easily reused or recycled;
- Are made from recycled materials;
- Do not contain toxic materials;
- Have minimal packaging, if any.

Take a stand and be heard. Show your commitment to using resources wisely by stating in bid packets that your organization expects suppliers to participate in waste prevention and recycling. Ask vendors to identify products that promote waste prevention and recycling.

2.11. Using Life Cycle Analysis (LCA) of products to raise awareness of waste

In order to build employees' and other stakeholders' understanding of horticultural waste, it is often helpful to take a lifecycle approach.

In this way, all inputs to and outputs from the system or supply chain are considered, from raw material extraction all the way to the end-use of the product and recycling of its wastes. By depicting them graphically, it can be easier to map out all of the processes involved and to build employees' and other stakeholders' awareness of these.

When considering the inputs to a horticultural LCA study, it is important to think of all aspects that feed into and out of the supply chain. Often, even LCA professionals exclude some important elements. For example, agricultural machinery manufacture, nursery production, waste management and raw materials transportation. By taking a full life cycle approach and considering where materials 'come from' and 'end up'

at their end-of-life, one may assess the implications of different waste management techniques. For example, using peat-based growing media for nursery plants results in very high levels of GHG emissions; alternatives with comparatively low GHG emissions include well-rotted compost, produced on-farm from composted organic matter, or coir – a natural fibre of coconut husks, which is also a by-product of the coconut industry.

Figure 17: depiction of the inputs to and outputs from a fresh produce supply chain that can be included in an LCA
Source: Bartazas *et al.*[133]

Both of these examples highlight the potential for waste products to be re-purposed for use in the horticulture industry as replacements for peat. For more information on compost and growing media see chapter 4 and 5.

By combining a life cycle assessment with a circular economic approach, it is possible to assess each individual waste stream occurring within the supply chain, to determine how it could be dealt with in a more sustainable manner. For more information on waste and the circular economy, see Chapter 2.

133 Bartazas et al (2015) Life cycle assessment of open field and greenhouse cultivation of lettuce and barley. *Information Processing in Agriculture* 2 191 – 207.

3. IMPLEMENTING AN INTEGRATED WASTE MANAGEMENT PLAN (IWMP)

The purpose of a waste management plan is to prepare a farm or a food processing site to effectively manage waste, debris and materials generated through their activities.

An effective waste management plan should aim to:

- Optimise use and material recoverability in the life cycle of products. Particularly for organic waste and packaging.
- Decrease material use in production.
- Improve the collection and disposal of waste.

3.1. Five key focus areas of the IWMP[134]

Selon l'Agence des États-Unis pour la protection de l'environnement, un PGID doit se concentrer sur cinq domaines clés, mis en exergue dans le tableau ci-dessous.

1. Identify potential waste streams	• What are the possible waste streams on your site? • Do any national or local laws or regulations apply to the potential waste streams? For example, the disposal and treatment of waste water used in production? • How much waste is expected to be generated by each waste stream? • Can the amount of potentially generated waste be reduced by means of source reduction (e.g. by packaging products in refillable containers?) or hazard mitigation (e.g., eliminating potential problematic wastes, such as chemicals) activities? • What organic waste can be reused on site for composting and or energy?
2. Evaluate the reuse and recycling program	• What reuse and recycling options (e.g. recycling facilities, end markets for reused and recycled products) are currently available to you? • Does your community have green local waste initiatives that encourage the creation of a reuse and recycling infrastructure?
3. Consider waste collection strategies	• How may the waste be separated into different waste streams before being removed from the site? • Can the volume of the waste be reduced? • How will the waste be collected and transported off-site?

134 www.epa.gov/homeland-security-waste/waste-management-benefits-planning-and-mitigation-activities-homeland.

4. Determine locations or criteria for waste management sites	• What locations are suitable for waste disposal? • Are contracts pre-negotiated for those sites? • What reuse, composting, recycling, treatment and disposal options are currently available in your community or region? • Which waste streams may each waste management facility accept? • How much of each waste stream can each facility receive? • Under what conditions, if at all, will specific facilities accept the waste?
5. Address health and safety considerations for waste management operations	• What are the risks associated with the potential waste streams and the use of decontamination technologies? • Do emergency personnel have appropriate training regarding waste handling and management? • Is personal protective equipment (PPE) available for handling different types of waste?

3.2. A Farm IWMP[135]

In the Food Supply Chain (FSC), a waste management plan should be based on reducing the use of products that cause environmental contamination and harm human health from production to distribution.

An IWMP should aim to ensure that waste constituents are recycled and reused to the maximum possible extent and have the least possible environmental impact.

Within horticulture, the site should also consider additional options for recovering energy from agricultural waste in the form of charcoal briquettes or biogas.

A farm IWMP should have short term and long term goals in line with the following stages.

Stage 1: Establish a system for managing solid waste on site

a) The site should identify sources of waste on site.

b) The waste should be quantified and categorized into different types of waste (including agricultural organic, household, chemical, and agricultural and special wastes such as electric waste) including projections for future waste generation.

c) The plan should identify key individuals that have to be trained on site to implement the waste management plan.

135 Rainforest Alliance, "A guide for social and environmental management system guide", 2010.

Stage 1: Identify, quantify and categorize waste streams, as well as points where waste is generated			
Main sources of waste	**Waste Management Plan**	**Waste type, quantity, point of generation**	**Responsible Individuals**
Food loss during picking, sorting, storage	• Identify areas where there is food loss (but the product retains its nutritional value) Calculating the amounts at different stages. • Train pickers on how to handle the fruit/ vegetable to reduce bruising and spoilage • Limit the amount of food that is placed and kept in its basket / container to avoid spoilage. • Consider whether any of the food can be transformed into new products. Eg. jams or paste. Is there a market? Can it be given to workers? • consider conservation methods such as drying to keep the food for longer periods. Is there a market? Can it be given to workers?	N. of kg during picking N. of kg during sorting N. of kg from transport	• Farm and / or waste manager • Pickers • Sorting staff at Warehouse • Drivers • marketing personnel

Organic waste from the farm	• identify different sources of organic waste (spoilt fruit, vegetables, clippings, grass, animal waste) • Introduce collection points for different types of organic waste, such as pits and collection containers. • Segregate waste destined for i) potential animal feed ii) composting/ soil enrichment iii) energy recovery (briquettes/ biogas) • Ensure that any liquid waste is disposed off into treatment ponds and tanks to filter out chemicals and hazardous content	N. of kg g during picking N. of kg during sorting and transport N. of kg during farm maintenance activities, cropping	• Farm and / or waste manager • Pickers • Farm field workers and maintenance staff
Organic waste from workers (household waste)	• Establish simple clear written procedures regarding waste and communicate these to workers (with pictures) on site, in living quarters • Provide different colour waste bins for segregating waste, for example: i) green for plastic ii) blue paper and cardboard iii) brown for food that can be composted iv) grey for metal v) yellow for glass vii) black for general (non recycled) • Recover any possible organic waste for i) composting/ soil enrichment ii) energy recovery (briquettes/ biogas) • Establish pits for organic household waste	N. of kg per person	• Farm and / or waste manager • Pickers • Farm maintenance staff

Inorganic waste (plastic, metals, glass) from workers	• Trash bins for inorganic waste, which is segregated into glass, cardboard, plastic, metal. • Collect waste and take to a named recycling center or authorized sanitary landfill. • Ensure any permits for burning waste are up to date and facilities are checked by local authorities yearly.	N. of kg of glass N. of kg of metal N. of kg of plastic	• Farm and / or waste manager • Workers on living and/ or working on site
Agrochemical containers	• Triple-wash and perforate containers • Store containers in a designated place in an orderly fashion take them to the nearest recycling center of the Agricultural Providers Association.	Number of containers	• Farm and / or waste manager • Chemical warehouse supervisor • Chemical applicators

Stage 2: Effectively dispose & treat waste to minimize environmental and social impact

a) The site should have a list of Recycling center options for some materials (townships, non-governmental organizations (NGOs), and ministries of the environment and natural resources) that are present locally and regionally.

b) The site should assess the efficiency and costs of the existing waste management system based on options for waste collection, segregation, transportation, treatment, disposal.

Stage 3: Establish the Recycle, Reduce, Reuse system as a priority

a) Look at reducing food loss by transforming products and identify cost savings from alternative food supplied to workers and/ or markets.

b) identify and prioritize issues of concern so that they could be addressed in a systematic and effective way.

c) Review how waste can be minimized at the point of its generation.

d) Investigate options for reuse of organic waste as a bi-product for fertilizer, energy generation.

Stage 3: Consider what can be Reused, Reduced, Recycled and/ or Recovered (4Rs)			
Main type of waste	**Waste Management Plan**	**Waste type, quantity, point of generation**	**Responsible Individuals**
Food loss during picking, sorting, storage	• Identify areas where there is food loss (but the product retains its nutritional value) Calculating the amounts at different stages. • Train pickers on how to handle the fruit/ vegetable to reduce bruising and spoilage • Limit the amount of food that is placed and kept in its basket / container to avoid spoilage. • Consider whether any of the food can be transformed into new products. Eg. jams or paste. Is there a market? Can it be given to workers? • consider conservation methods such as drying to keep the food for longer periods. Is there a market? Can it be given to workers? • Any spoilt or unusable food should be used as an organic waste waste stream below	N. of kg during picking N. of kg during sorting N. of kg from transport	• Farm and / or waste manager • Pickers • Sorting staff at Warehouse • Drivers • marketing personnel
Organic waste	• -Segregate waste destined for i) potential animal feed ii) composting/ soil enrichment iii) energy recovery (briquettes/ biogas) • Ensure that any liquid waste is disposed off into treatment ponds and tanks to filter out chemicals and hazardous content	N. of kg for animal feed & cost savings N. of kg for fertilizer and & cost savings N. of kg and energy recovered & cost savings	• Farm and / or waste manager

Plastic containers (from soda, juices)	• Collect plastic containers that contained liquids for human consumption and reuse these to: i) make insect traps ii) carry water for farming tasks or iii) make funnels for pouring fuel or other liquids.	N. of units	• Farm and /or waste manager
Fertiliser sacks	• Wash out and recover fertilizer sacks of jute or polyethylene and store in the fertilizer storeroom to be used during the harvest.	N. of units	• Farm and /or waste manager

Stage 4: Monitor and update the plan

a. Identify individuals who are responsible for managing the plan at different stages of waste generation.

b. Review the plan yearly to identify potential areas for improvement.

c. Review targets for waste minimization.

3.3. A waste self-assessment template[136]

The following template, based on the COLEACP Waste Self Assessment, is a useful tool, to identify key areas where you might need to improve data gathering and monitoring.

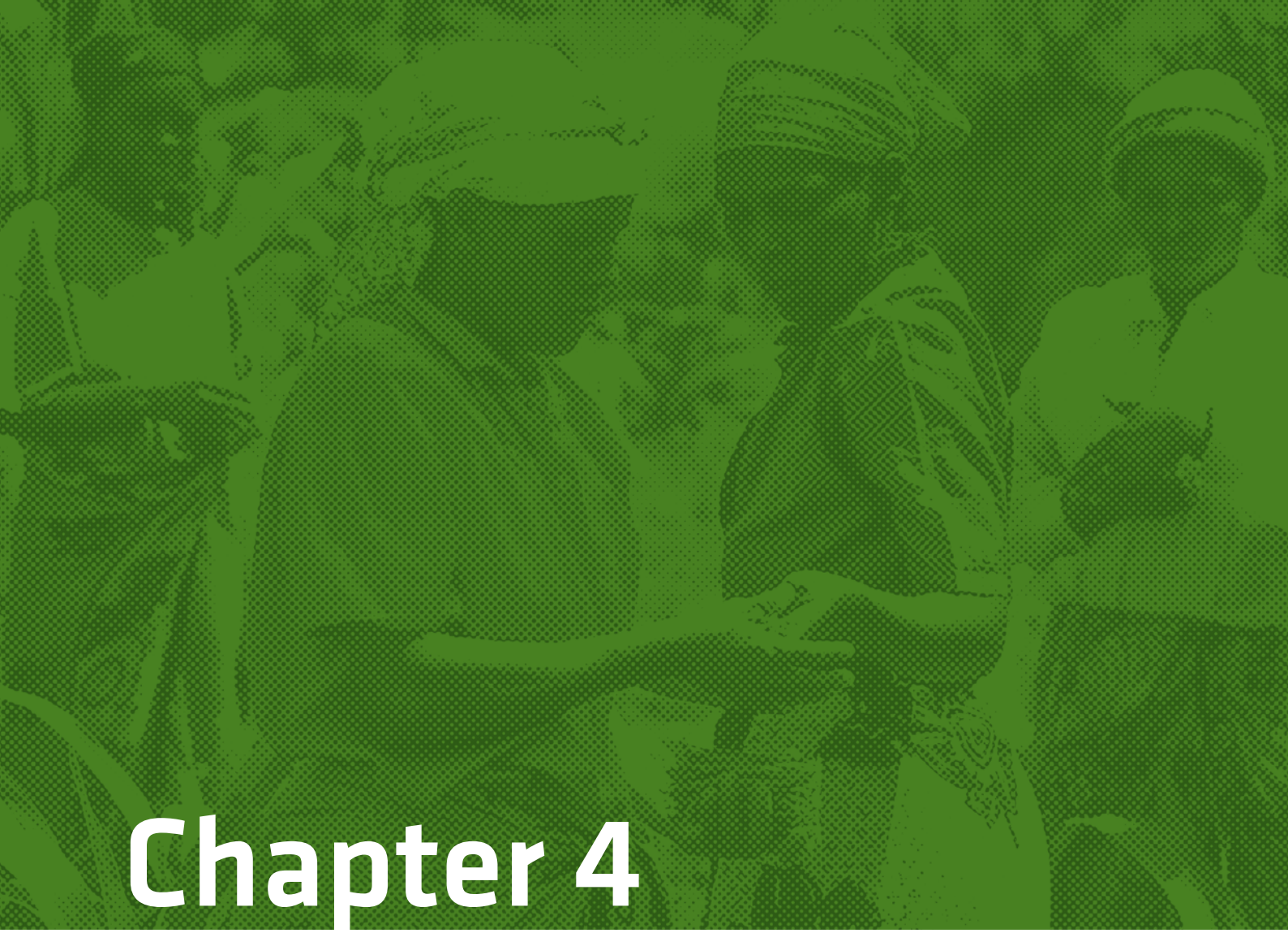
1	Managing waste	Please insert name		
1.1	Do you know the name of the national/local authority responsible for controlling and monitoring the management of waste from farms and food businesses?			
1.2	Are there waste recycling facilities in your area/country for different categories of waste (see list)?	Please tick yes for all that apply	Yes	N/A
		1. Crop by-products and non-marketable product		
		2. Paper, cardboard and wood		
		3. Plastics		
		4. Metals		
		5. Redundant equipment and machinery		

136 www.coleacp.org/en.

1.3	Have you and/or your staff been trained in how to dispose of hazardous waste in a way that avoids any harm to humans and the environment, and according to the regulations?	Hazardous waste includes: • Obsolete pesticides • Sewage • Other toxic substances such as heavy metals, polyaromatic hydrocarbons (PAHs) • Surplus pesticides (insecticides, herbicides, fungicides, rodenticides, fertilizers, thinning or crop setting agents). • Pesticide containers		
1.4	Have your outgrowers been trained in how to dispose of hazardous waste in a way that avoids any harm to humans and the environment, and according to the regulations?			
1.5	Is there a designated person responsible for overseeing and monitoring the handling of hazardous waste on your farm and premises?			
1.6	Do you have designated locations to store/handle waste safely (with hazardous waste segregated from non-hazardous waste)?			
1.7	Do you keep records of the quantity of different types of waste generated by your operations (see list)?	Do you know the volume/ weight of each of the following types of waste generated each year (tick yes for each that applies) by your operations?	**Yes**	**N/A**
		1. Empty agro-chemical containers		
		2. Plastic, paper and/or metal waste		
		3. Fuel and oil residues		
		4. Crop by-products		
		5. Obsolete agro-chemicals, laboratory waste, and other hazardous waste		

1.8	Do you reuse or recycle any of the following types of waste	Please tick yes for each of the following categories of waste which you currently reuse or recycle (at least in part):	**Yes**	**N/A**
		1. Crop by-products and non-marketable product (e.g composting, biofuels, alternative markets)		
		2. Paper, cardboard and wood		
		3. Plastics		
		4. Metals		
		5. Redundant equipment and machinery		
1.9	Do you work with your employees and suppliers to reduce waste (see list)?	Please tick yes for all that apply:	Yes	N/A
		1. Is there a designated member of staff responsible for monitoring and reducing waste?		
		2. Have you trained staff on why and how to reduce waste?		
		3. Do you have a purchasing policy in favour reducing waste?		
		4. Do you encourage your staff to reduce, reuse and recycle their household waste?		
		5. Have you raised awareness on how to reduce waste among your outgrowers?		

2	Do you have (and implement) a written waste management plan?	A waste management plan: • identifies sources of all hazardous and non-hazardous waste • has a system to measure and record quantities of waste generated • implements measures to reduce waste • implements measures to re-use and recycle waste • identifies the location, infrastructure and procedures for the safe storage of waste • has clear procedures for the safe dispose of waste • has a designated responsible person for the proper handling of waste • has an inventory that raises awareness of the amount and location of waste • has a programme to train staff and outgrowers on reducing and managing waste



Chapter 4

Waste recovery and the reuse of organic matter

1. CONVERTING OR RECYCLING WASTE: DECISIVE FACTORS TO CONSIDER

Waste recovery allows the reuse of organic matters by recycling, reusing and composting, in order to produce energy, enrich the soil and reduce the pollution and the use of natural resources.

According to the EC Waste Framework Directive 2008/98/EC waste recovery is "any operation, the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function".

In fact, waste recovery preserves resources through the use of waste instead of the use of other new raw materials.

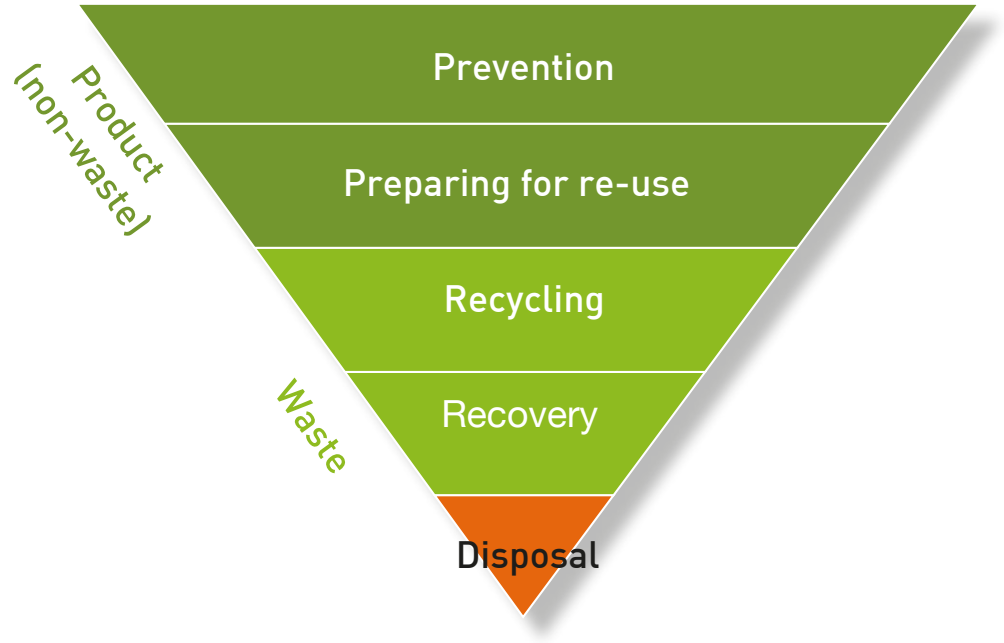


Figure 18: The Waste Framework Directive 2008
Source: EU[137]

The diagram highlights, that the first thing we have to think about is how to avoid producing waste. In doing so, we avoid producing an item/product that will be costly to produce and costly to dispose of or recycle.

137 http://ec.europa.eu/environment/waste/framework/.

1.1. Recycling waste: Decisive factors to consider

The amount of waste in every stage of our life is increasing and this waste means wasting money and spending our resources endlessly.

Recycling or converting has environmental, economic and social advantages:

- It reduces the demand of new resources.
- It prevents environmental pollution (less use of landfill).
- It reduces the amount of waste in landfills.
- It allows the use of materials that would otherwise be wasted.
- It allows for savings by cutting additional costs of new materials and reduces the amount spent on transporting waste. By recycling we avoid manufacturing new items and wasting ressources.
- It allows energy recovery by converting waste into energy, thereby reducing the cost of the energy. This impacts on the costs associated with the farm, and on the livelihoods of workers and smallholders, who can access cheap energy. It also allows people to work on recycling.

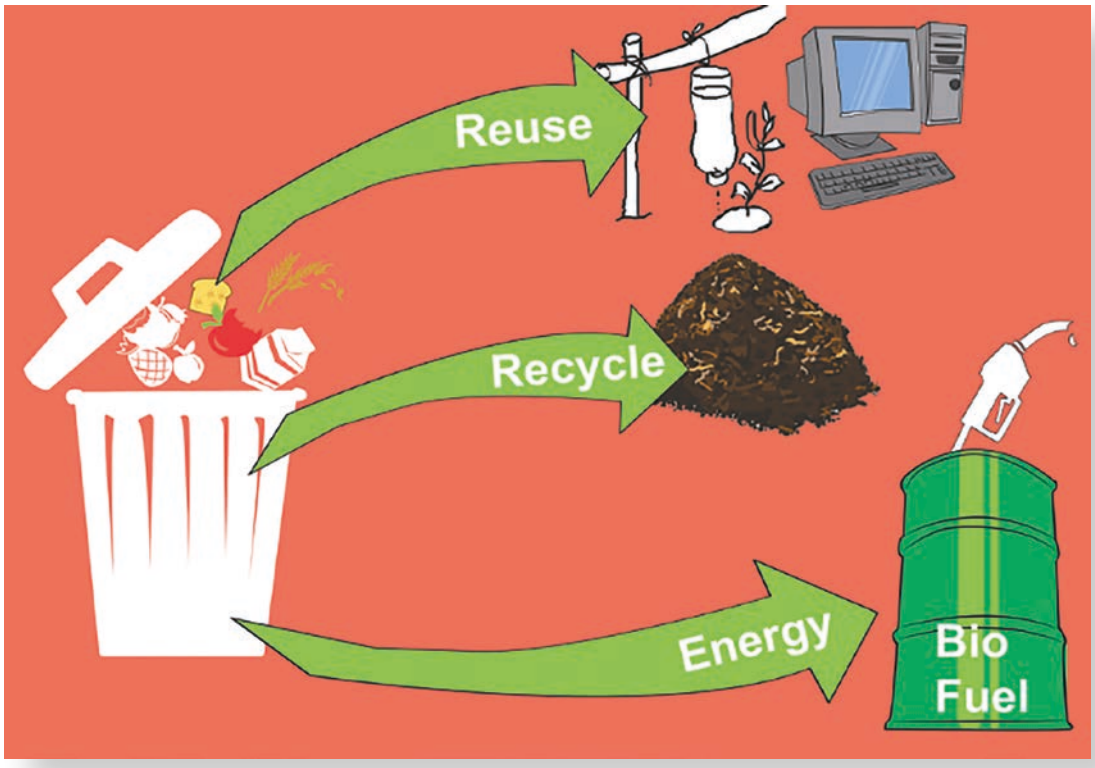


Figure 19: Parts and components from electrical equipment such as computers can be recovered and reused.

- What is recycling? Recycling is a process in which waste materials are treated in a way that they can be used again. Recycling is a ley component of modern waste management and is the third component of the "Reduce, Reuse, Recycle, Recover" waste hierarchy.[138]

- What is reusing? Reusing a product means to use it for the same or another purpose but without treatement. Less pollution, less manufacture. Reusing is always best then recycle but we cannot reuse everything (we can reuse a cardboard box, we might not reuse a piece of plastic but we can recycle it).

- What is converting? The process of converting a waste into a renewable energy, is known as Waste to Energy (WtE), a process that converts solid waste into electricity and/or heat. It is an ecological cost effective way of energy recovery.[139]

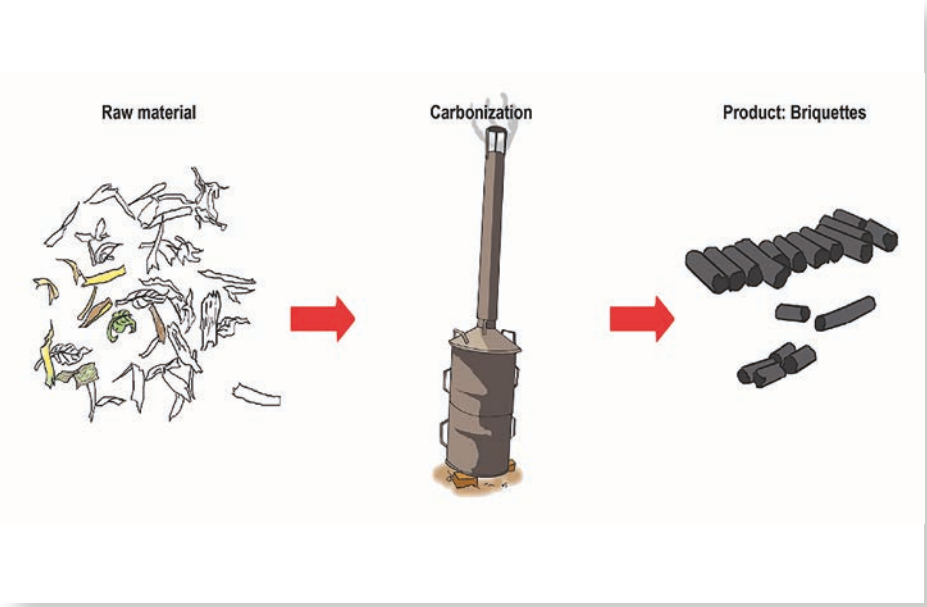


Figure 20: Converting organic waste into briquettes

Wasting food means wasting the water, land and energy that has been used to produce the food. Worldwide 30% to 40% of all food produced is either lost or wasted between the stages of production and consumption.[140]

138 Pundlik Rathod Conversion of waste material into useful products April 2014.

139 CEF Conserve Energy Future – www.conserve-energy-future.com/waste-to-energy.php).

140 B. Schiffers, *Soil Manual*, Chap. 5: "Preserve and restore soil fertility".

The choice to reuse, convert or recycle, depends on the products, on the premises available not only on site, but also in the country and on the capacity of each farm or production site to reuse or recycle.

Some products are only recyclable and others can be converted.

Glass, plastic, metal are recyclable in their majority but wood, plants, manure and others are more likely to be converted in a source of heat, energy or compost.

1.2. Plastic, glass and metal options for reuse and recycling

Although Glass, metals and plastics can be easily reused or recycled, when buried in a landfill they can take centuries to break down and sometimes leave harmful chemicals in the ground.

By recycling glass, a container can go from a recycling bin to a store shelf in as few as 30 days and save our natural resources such as limestone, sand and feldspar. Additionally, steel has a 66.2% recycling rate, which saves 60-74% of the energy used to produce a steel can.[141]

141 http://challengeforsustainability.org/toolkit/waste-reduction/recycle-glass-metal-and-plastic/.

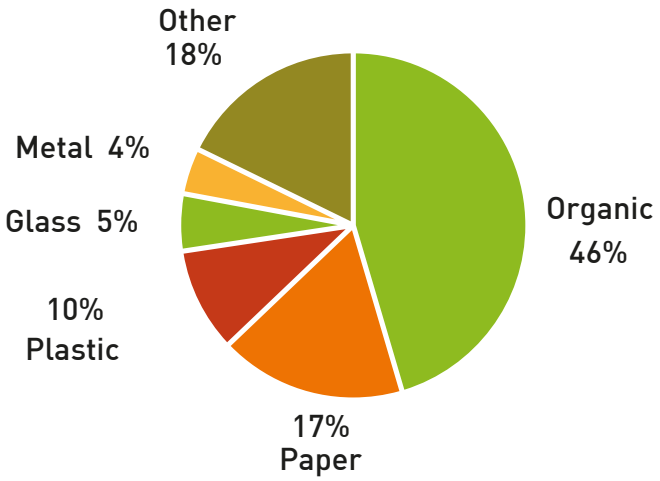


Figure 21: composition mondiale des déchets solides
Source: World Bank[142]

NB: Solid wastes include paper, plastic, glass, metal, waste from agriculture, food, manure. "Other Wastes" include liquid waste such as water, fertilizers, pesticides, leachates.

Plastic is the most difficult waste to recycle or reuse. As per the illustration below, number 1 and 2 are easily recyclable whereas code 7 being a mixture of plastic and other materials will be difficult to recycle. However most of the plastic we use as bottles, cans, bags or buckets are made from 1 to 4 components.[143]

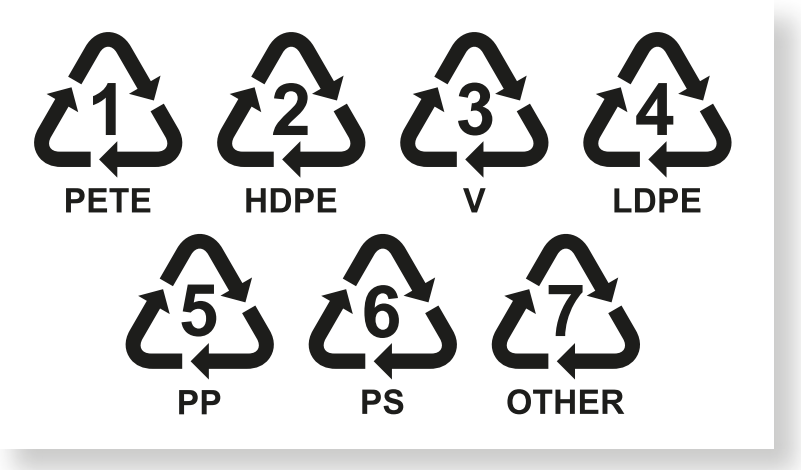


Figure 22: plastic compostion
To identify a type of plastic, find the small triangle made up of three arrows on the plastic.
For example, if you turn a bottle of water upside down, you should find the small triangle where there should be a number from 1 to 7.

142 World Bank – what a waste – a global review of solid waste management.
143 VIV BIZ CLUB.

Recycling is one of the most important actions currently available to reduce the impact on environment and represents one of the most dynamic areas in the plastics industry today. Recycling provides opportunities to reduce oil usage, carbon dioxide emissions and the quantities of waste requiring disposal. Here, we briefly set recycling into context against other waste-reduction strategies, namely reduction in material use through down gauging or product reuse, the use of alternative biodegradable materials and energy recovery as fuel.

While plastics have been recycled since the 1970s, the quantities that are recycled vary geographically, according to plastic type and application. Recycling of packaging materials has seen rapid expansion over the last decades in a number of countries. Advances in technologies and systems for the collection, sorting and reprocessing of recyclable plastics are creating new opportunities for recycling, and with the combined actions of the public, industry and governments it may be possible to divert the majority of plastic waste from landfills to recycling over the next decades.[144]

However certain governments as well as private companies, which recognize the pernicious effects of plastics have gone that one step further and banned their use. The example of the plastic bag, which is being progressively phased out across most retailers in the EU (by charging customers an extra amount for their use) has also been banned in countries like Rwanda and Senegal.

1.3. Advantages of glass, metal and plastic recycling and reuse

The table below highlights what the advantages of recycling glass, metal and plastics, as and the conditions that need to be met for the materials to be reused.

144 www.ncbi.nlm.nih.gov/pmc/articles/PMC2873020.

Glass	
	• 100% recyclable • avoid re-use of silica (sand), soda ash and limestone • 1ton of recycled = energy savings equals as 125l fuel oil and 1.2 t raw material • reduces non biodegradable waste in landfills • can be used for making mineral wool (insulation product), or as a substitute for Quartz for high strength porcelaine sanitary ware • can be used for building (bricks, glass wool thermal insulation) • they need to be emptied from other materials before recycling
Metal	
	• Aluminium can be recycled over and over • avoids use of bauxite • uses only 5% of the energy needed to produce new aluminium (saves coal and energy) • other metals can be recycled such as lead, copper and steel • metal needs to be free from other materials in order to be recylced
Plastic	
	• more than 60 types with codes (PET/PP/EPS...) and recycled according to the type of plastic material • mainly PET (used in soft drink packaging) and HDPE (plastic bottles and detergent bottles) are recycled • can be molten and reshapped, reused as small blocks for construction • plastic bags can be re-used for crafting or storing produce

1.4. Case study of Songhaï in Africa

The idea of the creation of Songhaï Centre (1983) came from Father Godfrey Nzamujo, who is a Dominican priest with a doctorate degree in electronics, microbiology, and development science.

At Songhaï, all waste is considered a 'by-product.' Nothing is lost and everything is transformed: the local production is transformed and distributed on site. These by-products are used to add value to other products and to create new goods and services, thereby preserving the environment, whilst generating an income.

Songhaï reuses almost 100% of what they produce, grow or use by transforming waste. For example they rebuild new agricultural machinery from the old and unusable pieces of metal, they recycle the plastic bottles, buckets and cans, they have metal furnaces, ceramic furnaces, they build ceramic water filters, ceramic coolers (to store vegetables), bricks for the construction. Songhaï has an holistic view on economics and social aspects. The idea is to help adquiring knowledge, being selfsufficient (as much as possible) and give human and social back up to the people who want to go into agriculture

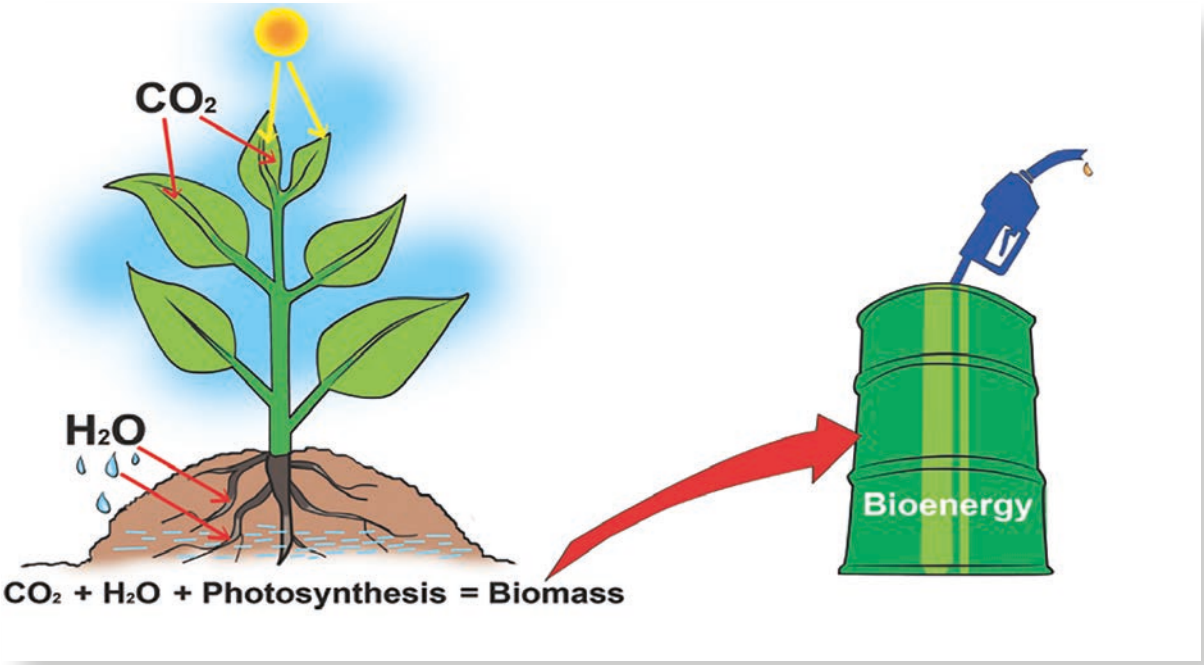
Photos: Songhaï Centre
Source: Songhaï[145]

1.5. Biomass: A unique opportunity for conversion

Biomass is the oldest fuel used by mankind. At the start of the humanity, we were using wood to produce our energy but in later centuries we replaced it with the use of fossil fuels. Today we understand that our dependency on fossil fuels in the long term is unsustainable, as it is not an infinite resource and we are destroying the environment by burning those fossil fuels. There is a renewed push for us to use renewable energy and this is where biomass presents a huge opportunity for the horticultural sector.

Biomass is produced by the carbon dioxide (CO_2) from the atmosphere and water absorbed by the plant roots, which are combined in the photosynthetic process to produce carbohydrates.

145 www.songhaï.org.



The term biomass encompasses a variety of fuels and technologies used to produce renewable energy. Biomass refers to land and water-based vegetation, organic wastes and photosynthetic organisms. These are non-fossil, renewable carbon resources from which energy can be produced and used as fossil fuel substitutes.

Energy from biomass and waste is often referred to as bioenergy. When plant material is burned for energy purposes carbon dioxide is released. However, because plants absorb carbon dioxide during their life cycle, the net emissions of carbon dioxide are zero. In this way, wood is said to be carbon neutral.[146] But only as long as we use scrap wood, forest residue or timber from forests that are specially grown for Biomass and sustainably managed sources.

Not only is biomass is a natural and clean energy, but it can be also a vector of cost savings by not using forest fossil fuels and **also a vector of employment** as we can see in the following graphs.

146 www.seai.ie/uploadedfiles/RenewableEnergy/REIOBiomassFactsheet.pdf.

Intensive production in Marginal Lands in Developing/Tropical countries - % Earnings for Each Activity:

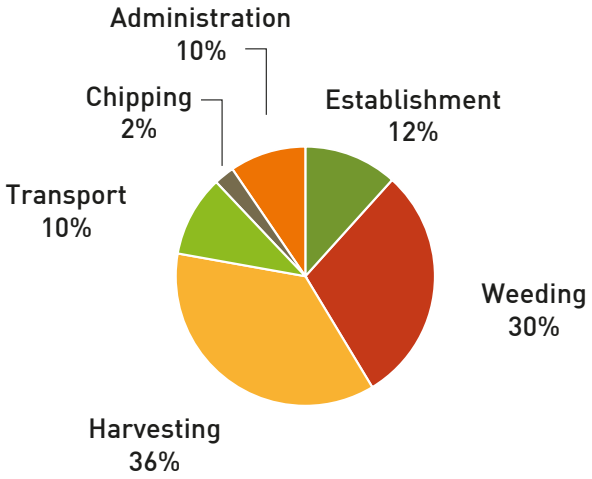
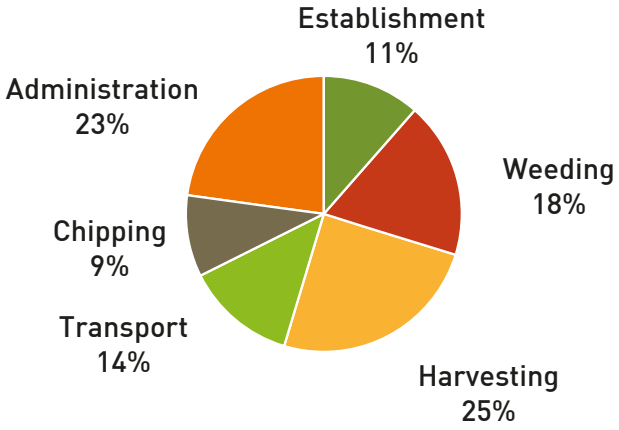


Figure 23: forest fuels – rural employment and earnings
Source: European Biomass Industry Association[147]

Large scale Woodfuel Production on Previously Forested Lands in Developing/ Tropical countries - % Earnings for Each Activity



1.5.1. Advantages of biomass as a source of energy[148]

The charts show, that obtaining energy from harvesting agricultural land is proportionally more costly than forestry with figures of 36% and 25% respectively. Many factors influence the differences, not just the physical differences in the biomass, between food crops and trees such as density, weight and bulk size but also the size of land and whether harvesting equipment is affordable for smaller producers.

147 Hector, B., 2000, "Forest fuels-rural employment and earnings", Department of Forest Management and Products, SLU, SE-750 07, Upsala, Suède- www.eubia.org/cms/wiki-biomass/employment-potential-in-figures/.

148 www.eubia.org/cms/wiki-biomass/employment-potential-in-figures/environmental-benefits/.

Whatever the case may be, there are numerous advantages to using biomass instead of traditional fuels. These include:

a) Energy self sufficiency

- Net reduction in CO_2 emissions – biomass is carbon neutral (there is no net increase in CO_2, the main greenhouse gas, in the atmosphere) and can save millions of tons of CO_2 emissions per annum. As long as it is not driving deforestation.

- It is an indigenous resource: which can reduce our current state of over-dependence on fuel imports and reduces the risk of cut off in supply.

- Biomass projects provide a valuable source of employment, especially in remote rural areas. Of course other industrialized sectors give work, but we are specifically talking about what Biomass can provide in terms of crossed benefits.

- The main employment sectors and industries are:
  - Fuel supply – cultivation of energy crops, recovery and transportation of wood wastes, forest residues, agricultural wastes;
  - Engineering consultants – feasibility studies, design and engineering/ construction management;
  - Environmental services – environmental impact assessments ;
  - Construction – roads, buildings, electrical infrastructure etc.;
  - Legal/Financing – planning, contractual and financing;
  - Manufacturing – there is significant potential for establishment of manufacturers of the various components of biofuel systems;
  - Maintenance, servicing and administration.

b) Environmental gains

- Biomass is sustainable and does not deplete future resources. As long as it is well managed and does not contribute to deforestation of primary forests.

- Energy forestry crops have a much greater diversity of wildlife and flora than arable or pasture land and careful design of energy crops will enhance local landscapes and provide recreational facilities.

c) Solution to the surplus waste

- Useful bioenergy can be recovered from various sources, in order of importance these are:
  - forest residues (e.g. wood chips, bark),
  - wood wastes (e.g. from sawmills),
  - household and agricultural residues (e.g. slurry and poultry waste) to generate heat and electricity, while at the same time dealing with the problem of waste disposal.

d) Biomass feedstock's/ sources of biomass can be divided into two streams

- Energy crops
  - allows to use short rotation forestry (such as eucalyptus);
  - energy crops have been known to compete with food on land;
  - needs to be well monitored and sustainably managed.

- Organic residues
  - are those that use agricultural waste.

1.5.2. Disadvantages of biomass as a source of energy

a) If not properly managed, access and use of land could be a significant issue. As crops grown for the purpose of generating only biomass can compete for food crops, in the use of arable land from farmers.

b) The growing of one type of crop as a source of biomass, can also lead to the loss of biodiversity in communities and affect wildlife.

c) If the biomass does not come from sustainably managed sources, it can also contribute to global deforestation which accounts for 15% of global GHG Emissions.

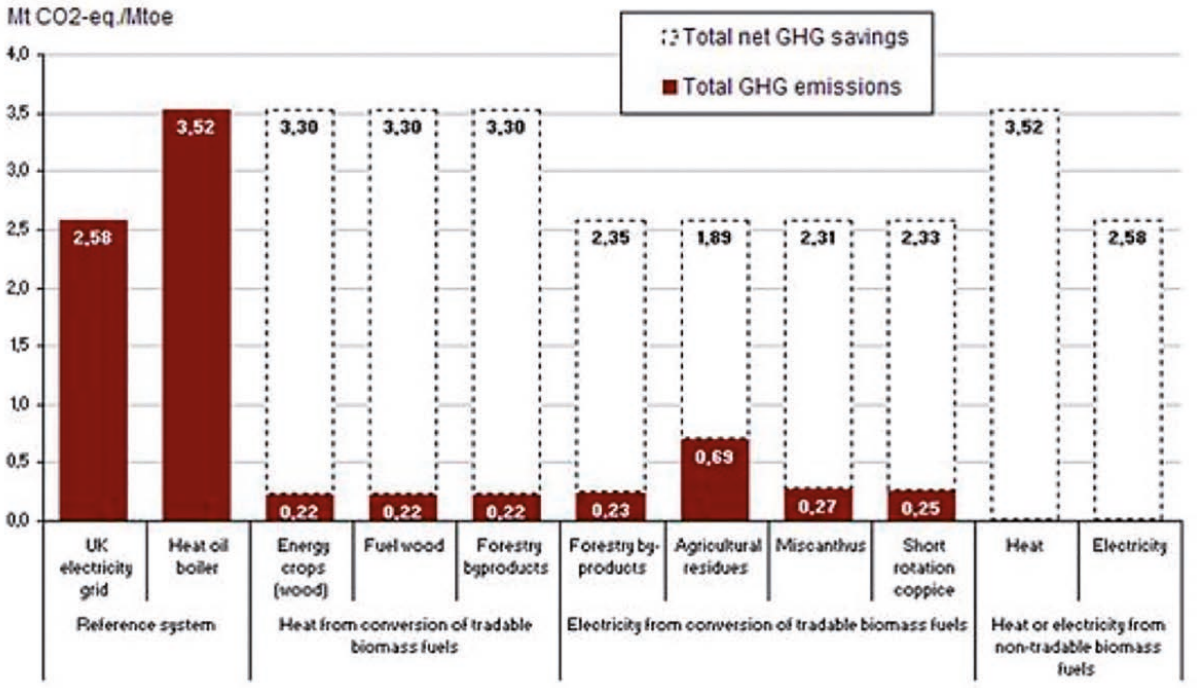


Figure 24: Employment potential and environmental benefits
Source: European Biomass Industry Association[149]

1.6. Animal and green waste for composting

Landfills are often the way to discard waste, but for animal and green waste, plants and discards of fruits, **compost is exponentially the best way to use the waste without spoiling it**.

However, building a compost plant **needs some space** (outdoor or indoor), **training and the right materials** to be composted.

Although all green waste, animal waste (mainly manure), even grey water can be composted. Composting requires a good balance of green organic materials (such as grass clipping, food scraps, manure) and brown organic materials (which are dry leaves, wood chips and branches) the green material provides nitrogen and the brown provides more carbon.

- **Waste manure as a resource**[150]

There are several factors to consider when using animal manure, which will impact on the success of its application to fertilize crops. The key issues to consider are:

- Availability of land for grazing;
- Livestock feed;
- Number and types of animals daily manure production;

149 *Ibid.*

150 This case study is based on a compost plant from Urs Hildebrandt's company Landmanagement in Austria. www.landmanagement.net.

- Livestock enclosures and bedding;
- Storage facilities to retain compost quality;
- Developing an effective manure management plan.

- **Land size and Mixed farming**

The traditional means of increasing crop production by simply expanding the area under cultivation is not feasible due to increased human population density. In many ACP countries **there has been a shift from extensive to more intensive mixed crop/ livestock farming systems**.

Mixed farming or diversified/ integrated systems are approaches that can be practiced mixing crops and/ or animal systems. Within this scenario manure is used as a fertilizer for crops. Fodder, crop residues and crop by-products are part of the animal feeds.

The size and type of land, as well as the type of crops and animals, will impact on the ability of a production site to be able to meet its requirements for fodder, given that animals may need to graze, or land may be required to grow fodder for animals. This will impact on the amount of animals that can be kept on site, and the amount of manure produced.

According to the FAO, mixed farming systems have both advantages and disadvantages.[151] Generally, farmers in mixed systems have to divide their attention and resources over several activities, thus leading to reduced economies of scale. Advantages include the **possibility of reducing risk, spreading labour and re-utilizing resources**. The importance of these advantages and disadvantages differs according to the sociocultural preferences of the farmers and to the biophysical conditions such as rainfall, radiation, soil type and disease pressure. For example, soils that are rather sandy tend to have low total nitrogen and phosphorus.

- **Livestock feed and grazing**

In many ACP countries, goats and cattle can be zero-grazed and fed mainly natural forages and crop residues. For example, maize stover. However, for dairy cattle, feed concentrate is often recommended as this impacts on the quality and quantity of milk produced. A study of farmers in Southern Tanzania, found dairy cattle produce 4 to 5 kg Dry Matter (DM) manure daily, where as local cattle produce only 2kg DM manure daily.

Pigs may be given household food waste and some additional crop residue, such as maize. Where a site produces its own forage it needs to be able to produce enough quantities to feed the animals which it will sustain. This requires land and ultimately it will determine whether a site can produce enough compost to meet its needs and therefore develop a fully integrated composting system or whether it should use a diversified system (using animal compost and chemical fertilisers).

151 FAO : Mixed-crop: Livestock farming, www.fao.org/docrep/004/Y0501E/y0501e03.htm.

- **Number and types of animals daily manure production**

Manure can be generated and collected from liquid (urine) and solid (feces) waste from livestock, such as goats, pigs and poultry, horses and cattle. The Nutrient values are related to solids concentrations whereby, the higher the solids concentration, the higher the nutrient concentration.

It is important to measure how much waste is generated by livestock for each site and to test manure quality to check for nutrients such as Nitrogen (N), phosphorus (P), potassium (K) and organic carbon (C).

	Size[a]	Total manure[b]			Water[c]	Density[c]	TS[d]	VS[c]	BOD_5	Nutrient content		
Animal	**(lbs)**	**(lbs)**	**(cu ft)**	**(gal)**	**(%)**	**(lb/ft³)**	**(lb/day)**	**(lb/day)**	**(lb/day)**	**(lbs N)[d]**	**(lbs P_2O_5)[d]**	**(K_2O)**
Dairy												
Calf	150	12	0.18	1.38	88	65	1.4	1.2	0.19	0.06	0.01[c]	0.05
	250	20	0.31	2.30	88	65	2.4	2.0	0.31	0.11	0.02[c]	0.09
Heifer	750	45	0.70	5.21	88	65	6.7	5.7	0.69	0.23	0.08[c]	0.23
	1,000	60	0.93	6.95	88	65	8.9	7.6	0.92	0.30	0.10[c]	0.31
Lactating cow	1,000	111	1.79	13.36	88	62	14.3	12.1	1.67	0.72	0.37[c]	0.40
	1,400	155	2.50	18.70	88	62	20.0	17.0	2.34	1.01	0.52[c]	0.57
Dry cow	1,000	51	0.82	6.14	88	62	6.5	5.5	0.75	0.30	0.11[c]	0.24
	1,400	71	1.15	8.60	88	62	9.1	7.7	1.04	0.42	0.15[c]	0.33
	1,700	87	1.40	10.45	88	62	11.0	9.3	1.27	0.51	0.18[c]	0.40
Veal	250	6.6	0.11	0.79	96	62	0.26	0.11	0.04	0.03	0.02	0.05[d]
Beef												
Calf (confinment)	450	48	0.76	5.66	92	63	3.81	3.20	1.06	0.20	0.09	0.16
	650	69	1.09	8.18	92	63	5.51	4.63	1.54	0.29	0.13	0.23
Finishing	750	37	0.59	4.40	92	63	2.97	2.42[d]	0.60	0.27	0.08	0.17
	1,100	54	0.86	6.46	92	63	4.35	3.55[d]	0.89	0.40	0.12	0.25
Cow (confinment)	1,000	92	1.46	10.91	88	63	11.0	9.38	2.04	0.35	0.18	0.29
Swine												
Nursery	25	1.9	0.03	0.23	89	62	0.21	0.17	0.06	0.02	0.01	0.01
	40	3.0	0.05	0.37	89	62	0.33	0.27	0.10	0.03	0.01	0.02
Finishing	150	7.4	0.12	0.89	89	62	0.82	0.65	0.23	0.09	0.03	0.04
	180	8.9	0.14	1.07	89	62	0.98	0.78	0.28	0.10	0.04	0.05
	220	10.9	0.18	1.31	89	62	1.20	0.96	0.34	0.13	0.05	0.06
	260	12.8	0.21	1.55	89	62	1.41	1.13	0.41	0.15	0.05	0.08
	300	14.8	0.24	1.79	89	62	1.63	1.30	0.47	0.17	0.06	0.09
Gestating	300	6.8	0.11	0.82	91	62	0.61	0.52	0.21	0.05	0.03	0.04
	400	9.1	0.15	1.10	91	62	0.82	0.70	0.28	0.06	0.04	0.05
	500	11.4	0.18	1.37	91	62	1.02	0.87	0.35	0.08	0.05	0.06
Lactating	375	17.5	0.28	2.08	90	63	1.75	1.58	0.58	0.17	0.11	0.13
	500	23.4	0.37	2.78	90	63	2.34	2.11	0.78	0.22	0.15	0.18
	600	28.1	0.45	3.33	90	63	2.81	2.53	0.93	0.27	0.18	0.21
Boar[c]	300	6.2	0.10	0.74	91	62	0.57	0.51	0.20	0.04	0.03	0.03
	400	8.2	0.13	0.99	91	62	0.75	0.67	0.26	0.06	0.05	0.05
	500	10.3	0.17	1.24	91	62	0.94	0.84	0.33	0.07	0.06	0.06
Poultry												
Broiler	2	0.19	0.003	0.023	74	63	0.050	0.038	0.011	0.0021	0.0014	0.0010
Layer	3	0.15	0.002	0.017	75	65	0.037	0.027	0.008	0.0026	0.0008	0.0012
Turkey (female)	10	0.47	0.007	0.056	75	63	0.117	0.088	0.034	0.0078	0.0051	0.0034
Turkey (male)	20	0.74	0.012	0.088	75	63	0.186	0.139	0.054	0.0111	0.0074	0.0048
Duck	4	0.44	0.007	0.053	73	62	0.118	0.089	0.016	0.0043	0.0034	0.0026

Figure 25: Daily manure production characteristics, as excreted (head per day)
Source: MWPS[152]

N.B. The characteristics of manure for individual situations can vary by 30% or more from table values due to genetics, dietary options and varioations in feed nutrient concentration, animal performance and individual farm management.

152 MWPS: Manure Characteristics, Manure management systems series, Second Edition http://msue.anr.msu.edu/uploads/files/ManureCharacteristicsMWPS-18_1.pdf.

- **Livestock enclosures and bedding**

The way that animals are kept on the farm, impacts on how much manure can be recovered. According to studies conducted in Tanzania, feeding systems of local cattle and goats through free grazing can result in a loss of 60-70% of the manure. Thus manure that can be recovered for use in the crop field is only 30-40%.[153]

For **animals that are kept indoors, it is much easier to collect manure**, and the use of bedding preserves much of the urine nitrogen in the manure (Raussen 1997). However, where animals are kept in a corralled area there are **substantial losses of nutrients through volatilisation and leaching** (Kichman, 1985; Murwira, 1995).[154]

Many sites have moved towards the introduction of concrete floors for their animal barns, to facilitate cleaning. Notwithstanding, bedding is still often used to create comfort for the animals and to facilitate the collection of urine for composting. There are also possibilities for constructing concrete chambers besides the animal barn to capture urine.Finally, it is interesting to note, that living quarters can affect the nitrogen content of manure. A study in Tanzania found that nitrogen content was higher for indoor composted manure (1.96% DM) in comparison to kraal manure (1.13% DM) from animals reared in an outdoor corral. This is a result of leaching and volatilasation.[155]

- **Storage facilities to retain compost quality**

When animal manure is left in the open air, **it will lose most of its potassium and nitrogen as well as some of its phosphorus**. Varying amounts of other nutrients are lost through volatilisation and leaching (Kwakye, 1980; Matsumoto *et al.*, 1997). Thus effective manure storage is required to reduce nutrient losses from manure.

Composting manure in a barn or in a covered area is best practice and is a cost effective method for generating a farm's own fertiliser. For example, In Tanzania, farmers build manure barns with wood slab walls and a thatched roof. The barns have 4-5 cubicles, whereby fresh manure can be piled in the first cubicle and after one month turned to

153 FAO : Mixed-crop: Livestock farming, www.fao.org/docrep/004/Y0501E/y0501e03.htm.

154 Jackson HL, Mtengeti, EJ " Livestock Research for Rural Development 17 (10) "Assessment of animal manure production, management and utilization in Southern Highlands of Tanzania' Department of Animal Science and Production, Sokoine University of Agriculture.

155 *Ibid.*

the next cubical and to the next in the coming months until the 4th cubicle and thereafter stored in the 5th cubicle ready to be applied to the crop field. According to Rynk (2004), 4 to 6 months is enough time to reflect the benefits from composted manure, especially moisture loss and destruction of weed seeds.[156]

- **Land size and crops to be fertilized**

In order to develop a more mixed farming system using animal manure as compost, a site must evaluate the type of nutrients that are required for its crops, calculate the land size and estimate how much manure it can produce on site. It is not always necessary to develop a manure management plan, but it can help the planning process in converting to a full or partial self-sufficient composting system. According to PennState Extension,[157] **the following are important steps** in developing a manure management plan on a farm:

- Evaluate your requirements

1) Take soil tests of all your crop fields.
2) Develop a farm map.
3) Determine the average crop yields for the various crops.
4) If the farm has no qualified agricultural extension staff, professional help should be sought in evaluating the needs of the farm for manure.

- Know where and when to apply manure

5) Identify nearby water wells, streams (lakes and ponds), and sinkholes that require manure setbacks. A minimum of 10 metres is recommended.
6) Look for fields (considering slope, cover and setbacks) where manure application will be possible and of lowest risk for manure runoff.
7) Determine if winter manure application is necessary.

- Maintain nutrients in the manurefumier

8) Check your manure storages for problems.
   Leaks, cracks, bank erosion, trees and woody shrubs, holes, tears, overtopping, etc.
9) Check storage areas (barnyards, feedlots, exercise lots) for runoff to nearby streams or other water bodies.
10) Look for good manure stacking areas if this practice will be necessary.
11) Check your pasture for meeting the dense vegetation standard (average of 3" of growth across the pasture throughout the growing season).

156 Jackson HL, Mtengeti, EJ " Livestock Research for Rural Development 17 (10) "Assessment of animal manure production, management and utilization in Southern Highlands of Tanzania' Department of Animal Science and Production, Sokoine University of Agriculture.

157 The Pennsilvanya State University, www.extension.psu.edu/programs/nutrient-management/manure/plan-writing/preparing-to-write-a-manure-management-plan.

What ?	Where ?	Spread-able Area	When ? Identify Restrictions
Non-spreading Area	Fields where manure would not normally be spread; non-farmed fields, woodlands or fields simply to far away from the farm buildings.	n/a	DO NOT SPREAD
Water	Any ditches, watercourses and ponds. Also springs, wells or boreholes where water is used for human consumption and farm dairies, including any on neighbouring land close to the farm boundary.	n/a	DO NOT SPREAD
Don't spread Area	Areas where manure shouldn't be spread. At least 10m either side of all ditches and watercourses: 50m around springs, wells and boreholes; streep slopes with a high risk of run-off throughout the year; and Environmentally Sensitive Areas, SSSI's, or other land subject to management agreements.	n/a	DO NOT SPREAD
High Risk Area	Fields next to a watercourse, spring or borehole with soil at field capacity with moderate slope or slowly permeable soil; where soil depth over fissured rock is less than 30cm; with effective pipe or field drains.		
Very High Risk Area	Fields likely to flood sometime in most winters; next to a watercourse, spring or borehole; where surface is severely compacted, waterlogged or have a sleep slope and the soil is a field capacity, has a moderate slope and slowly permeable soil.		
Low Risk Area	All other areas not already marked.		
Total Spreadable Area Available		0	

Figure 26: Manure management plan
Source: Red Tractor[158]

1.7. Developing a compost plan

There are different types of composting methods/technologies, all using aerobic systems (aerobic composting use bacteria and oxygen in order to replicate natural decomposition).

158 Red Tractor, Manure Management Plan
http://assurance.redtractor.org.uk/contentfiles/Farmers-5605.pdf?_=636118632539489928.

This process is used with plants and waste with a high level of nitrogen (hence the need to add products such as manure and black waste to bring carbon) and it encourages a type of bacteria that produces and needs to live in high temperatures (65°C) but also requires a lot of humidity (55 to 60%).[159]

Figure 27: Sources of organic waste for compost

Some examples of composting systems most adapted to ACP countries are:

- Industrial scale composting processes: in-vessel composting, aeratic static pile composting, vermicomposting, windrow composting. For larger producers in ACP countries, windrow composting is the most adapted methodology.
- Vermicomposting: composting using various species of worms to create a heterogeneous ixture of decomposing vegetable and food waste.
- Composting toilet: collects human excreta that is added to a compost heap together with sawdust and straw, where pathogens are destroyed.
- Black soldier fly larvae composting: they have shown to be able to rapidly consume large amounts of organic waste when kept at 31.8°C.

159 Landmanagement – (Humus & aerobe gelenkte Kompostierung 2015) - www.landmanagement.net.

1.8. Case study of a windrow composting system

Windrow composting is the production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows (windrows).[160] This method is suited to producing large volumes of compost.

The method of Windrow composting is one of the best ways of composting on large fams across most as this type of composting can be used everywhere in the world.

A controlled windrow compost can be ready in 6 weeks with careful care and in the right environmental conditions, which means a good combination of both climate and plant.

The compost piles need to be moved manually or with specific machinery on a regular basis (twice a day to start with and up to 3 times a week at the end)

As the compost is ready in 6 weeks, there is a continuous supply. Farmers can have a continuous compost, every time they use a pile another is ready to be prepared.

There are no bad odours where there is a carefull control of the descomposition, and we can prevent the anaerobic (without oxygen) descomposition from the start. The putrefaction odours produced by the raw material disappear after 1 to 3 days.

The leaching and water infliltration will be prevented by having a slope on the soil of 3 to 5% so the leaching and water can be tracked and reuse as fertilizer. The compost pile should be constructed in the following way:

1. The lower cap of the pile should be composed of dry material for carbon (straw, dry palm leaves).

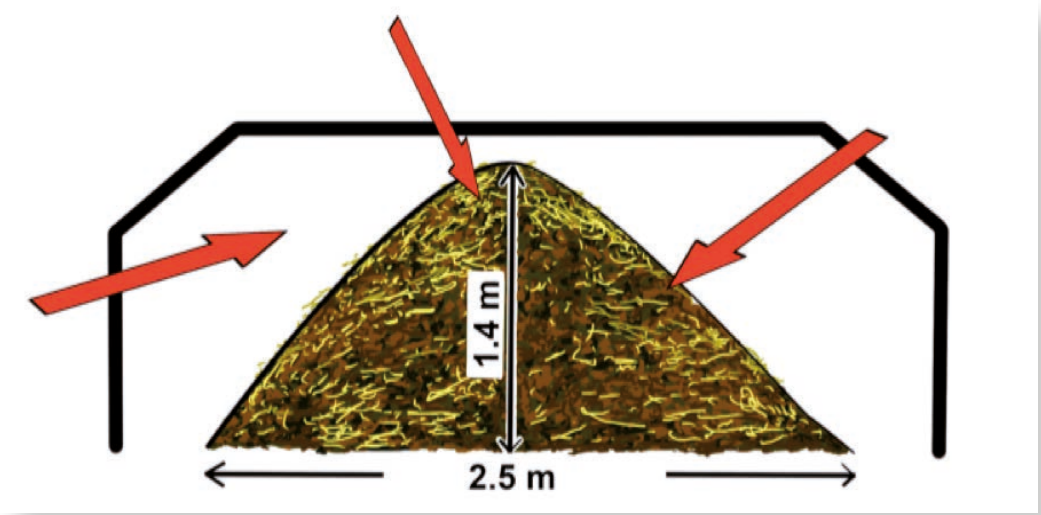
2. A second cap of humid ingredients such as fruits, vegetables, green leaves, grass (not more than 10%) is added to bring nitrogen and humidty and to allow bacteria to develop.

3. A third cap with dry material again and a 4th cap with humid ingredients is finally added. It must be completed with manure and 10% argilous soil. The soil added has argilous mineral necessary for the growth of the humus (see below).

160 This case study is based on a compost plant from Urs Hildebrandt's company Landmanagement in Austria. www.landmanagement.net.

Photo: An example of windrow composting on a farm

Photo: The ideal pile should be 2,5 m large on 1,5 m high



N.B.: Keeping a certain height allows low pressure on the raw marerial and allows the internal structure for CO_2 flow for several hours after moving the pile.

1.8.1. Classical mistakes to avoid for organic composting

The following materials should NOT be used for composting

- Charcoal ashes: The high carbon dioxide content interferes with oxygen supply in the composting system thus slowing down the process.
- Dog and Cat manure: This contains harmful pathogens.
- Any organic matter likely to be contaminated by pests or disease.
- Eucalyptus and cassia tree leaves or any biomass suspected to contain substances toxic to microbes.
- Meat and animal fat.

The temperature under 65 °C allows a good compost process and no burning of the compost, humidity is kept at a good level and nutriments are kept also.

Photo: Urs Hildebrandt checking the temperature and humidity of a pile[161]

Figure 28: Comparison of composting methods
Source: Powerknot.com[162]

Process	Odor	Pests	Maintenance	Location	Input	Time
Aerated Static pile	High	High	Moderate	Outdoors	Organic waste	1 to 3 months
Vermi-composting	Moderate	Moderate	Moderate	Outdoors	Soft organic waste	1 to 2 months
In-Vessel	Low	None	Low	Outdoors/ indoors	Organic waste	24h to 3 months
Windrow	Moderate	High	High	Outdoors	Organic waste	6 weeks to 6 months

161 Alexandra Farnos, Impages of Almeria 2017 and Austria 2015.

162 www.powerknot.com/2012/07/23/aerobic-composting-vs-anaerobic-composting/.

1.8.2. Requirements for starting a compost system

There are several specific requirements to build up a compost site.[163] The following is based on the tools and conditions required to follow the Windrow method, as we consider this to be **the most representative to our ACP audience.**

To establish a composting facility a number of items and considerations to be taken into account before implementing the Windrow method.

A brief description of these is given below:

a) Composting site requirements

- The site selected needs a 3 to 5% gradient slope, as it prevents watering from destroying the hill. The slope cannot be lateral; the leaking water of the windrows must come from the lower end.
- The site has to be large enough to build up several windrows, to have a sorting place and a place for each component (dry material, green grass, soil, manure).
- There site will need protection from the wind. It is useful to be near trees or even to plant trees around the area.
- Water availability is essential: this can be water from a shaft, from a small river or from treated grey water, as long as the water is available in quick supply.

163 www.ruaf.org/sites/default/files/Low%20costs%20composting%20training%20manual.pdf.

- The size of the compost plant must be adequate to the needs of the farm and the flux of components. The need is more or less 1sqm of space for each m3 of compostable material.

- The composting ground must be well selected, as it is not suitable to compost on sand or natural land as the water will leak.

- It is important to separate the water coming from the compost plant and from the storage plant. (as the leaking water from the compost plant is very concentrated).

- It is always good to plan for a larger space than needed to allow for growth.

b) Personnel requirements

Composting is a labour intensive activity and labour requirement need to be planned for carefully taking into each step. At least one person should be in charge of the compost plant, daily monitoring the work and recording what has been done.

c) Tool requirements

Various types of equipment which include wheelbarrows, pangas, shovels, sieves and, packaging materials are required before this activity is started. As well as the technical equipment below.

d) Composting organic waste material

Sustained supply of green (wet) and dry waste types is very important. These two waste types could be composed of the materials listed below:

i) *Green (wet) wastes:* These materials are considered as high quality because they contain high amounts of nitrogen.
- Food remains including egg shells, bones (without meat or fat) (but not more than 10% and as long they are not rotten).
- Fruit and vegetable peelings and discards from the farm.
- Freshly cut grass, tree leaves, weeds etc.

ii) *Dry wastes:* These can include dry grass and tree leaves. As well as materials such as saw dust from timber, straw and maize stalks.

iii) *Argilous soil:* This will bring the essential minerals to the humus. These have a high carbon content and they regulate the rate of decomposition. Wood ash may be used, if available to act as a source of major elements such as potassium calcium and magnesium.

iv) ***Having at least one of the following materials in small quantities is also a pre-requisite:*** Coffee pulp, animal manure such as of chicken, goat, cow sheep, rabbit and also dried blood, bone and fishmeal. These materials are required as they act as a catalyst, which help speed up the process. It is always better to have manure from vegetarian animals.

Figure 27: Materials needed for Windrow Composting and uses

Material for checking	What to check	Time line
Humidity needs to be controlled, using a humidity controller or by sight. If there is not enough humidity the straw will not discompose and will be visible still after 5 or 6 weeks.	**Humidity:** Levels should be 50% to 60%.	Check humidity every day. Use a special blanket to put on top of the windrows to keep humidity. Water must be added when turning the piles.
$C0_2$ gauge	**CO_2:** It should not be over 8% as higher concentration will asphyxiate the aerobic microlife.	Use a CO_2 controller on the lower part of the windrow, which is where the higher concentration of CO_2 will be.
Digital thermometer	**Temperature:** The Ideal temperature is 65°C as it prevents pathogenic infection to develop	Check temperature every day with digital thermometer, really inside the pile, on the highest part that will be the warmest.
	Oxygen: The concentration should be 5% to 12%.	Compost needs to be moved in order to get oxygen to break down the waste materials. Too much oxygen indicates that too much air is circulating therefore can cause excess of heat removal.
Pitchfork or tractor	Moving piles helps oxygen and CO_2 to be well balanced and allows the windrow to compost well	It needs to be done on a daily basis, to turn the pile by keeping always the same form and adding water during the process. It is easier with a tractor mover but can also be done manually.

1.9. Timelines for composting

1.9.1. Processus de compostage

The overall process of composting will **take roughly 6 weeks**. However, it is important to bear in mind that each of the six steps below happens withing specific timelines:

- Step 1 - Day 1

Prepare two sites, the first one for construction of the compost heap while the second one will be used for the storage of the compost material. The land should be cleared of all vegetation and loosened to allow water drainage.

• Step 2 – Day 2

Measure a space of land preferably 2.5m by 1.4m at one edge of the land. Evenly spread a layer of larger dry wastes (small tree branches, straw, banana leaves etc.) up to a thickness of up to 15cm. Add a layer of smaller dry vegetation (chop/shred if necessary) on top of this, to make up the layer to about 30cm. Sprinkle water to moisten. The dry layer is important, as it will allow air to pass freely through the pile. The dry layer is then followed by a layer of 30cm of green wastes. If possible, the green waste layer should then be covered with 2.5cm of coffee pulp or animal manure or finished compost. Precaution must be taken when balancing these two important layers, as these are the layers that determine the decomposing rate of a pile Moisten the pile, and then repeat this process of layering until the pile is about 1.4m high. Remember to water each of the dry layers.

• Step 3 – Day 3 to 5

Once the pile has been built, insert a long sharpened stick diagonally right through to the centre of the pile and leave the process to start. The stick acts like a thermometer. This is indicated by steam seen flowing from the pile and hotness of the part of that stick that was driven into the pile on completion of layering If the stick is hot, the process is going well. If the stick is not hot, the pile may need more or less water, and/or aeration. If the stick shows signs of a white substance on it, the pile will need more water added to it. To increase the amount of air, the pile should be turned more frequently.

• Step 4 – Day 7

Turn the pile once a week. Always water the pile when turning to maintain humidity.

• Step 5 – Once a week for 6-8 weeks

Within one week, the pile shall have reduced by almost a quarter. This will reduce the air spaces in the pile and most moisture will have escaped due to high temperatures. If the pile is not turned to improve these conditions the process would change into an anaerobic process, which is slow, time consuming, and unhygienic. Turning also promotes uniform decomposition of all the wastes. Well-balanced compost pile will always keep gaining higher to and above) survival, thereby slowing down the composting process. The turning process is necessary on a weekly basis till between 6 to 8 weeks when the temperature of the pile becomes cool which is an indication that the entire organic fraction has decomposed.

The compost will be ready when:

- the carbon to nitrogen (C/N) ratio is obtained (optimal is C/N ratio of 30);
- the texture of the compost is fine, looking like soil;
- the colour is dark brown to black;
- we have absence of inert materials (plastic, glass, rocks);
- the ph should be between 5,5 to 7,8;
- there is no odours (bad smelling);

1.9.2. Advantages of Composting

Composting reduces the amount of waste each of us sends to the landfill. Up to 30% of the material we send to landfill is organic and could be composted at home. Composting has other benefits too. Applying finished compost returns nutrients to the land, holds moisture and contributes to watershed health by controlling runoff and naturally fertilizes and provides structure to the soil.

Using the organic waste of the farms allows a reduction in costs:

- No cost of transportation of the waste;
- No cost to pay for disposal;
- It is beneficial for the soil and reduces the use of fertilizers (chemical) and/or soil amendments. This is the preferred system for farmers undergoing organic certification;
- It can be sold by the farmers to other farms (as finished compost or liquid fertilizer);
- All fruits and vegetables, flowers, leafs, grass, wooden stocks, straw, etc can be used from the production farm (including biodegradable linen used to sustain crops), up to 95% of the green waste of the farm can be used;
- Compost can be applied to the field whenever it is needed;
- Composting reduces the the high level of nitrogen contained into the manure into a more stable form, so there is less leaching and therefore less pollution of the soil;
- It is the better option for composting organic product (cultivated in organic agriculture) to avoid having pesticides and fertilizers in the compost.

Overall there are fertilizer savings and sales or exchanges that can use up to 95% of organic waste.

2. SOIL ENRICHMENT

Healthy soils need a good balance of Nitrogen (N), potassium (K) and phosphorous (P) as fertilizers.

- **A healthy soil increases:**

  - Soil carbon (which reverses climate change);
  - Water holding capacity and infiltration;
  - Soil aggregation;
  - Soil life;
  - Nutrient availability;
  - Retention.

- **Aerobic compost:**

  - Increases biodiversity in soils;
  - Activates and reestablishes the fertility of the soil;
  - Strengthen the quality of the soil;
  - Brings rich organic material;
  - Balances the minerals.

Photo: Soil structure, after several years of use of compost we can see that the soil is lighter and roots are appearent[164]

- **Anaerobic composting:**

  - Produces a liquid fertilizer ;
  - It needs to be processed in bins, with no oxygen, as the waste will be putrefacted ;

164 Alexandra Farnos: Landmanagement 2015 Austria.

- It produces biogas, that can be used as a natural fuel, but it is less useful in terms of compost needs.

Planting and growing local herbacaes, in rotation allows oxygenation of the soil and reuse of the plant into compost or as a dry grass after cut left on the soil.

Straw can be also left on the soil to avoid water evaporation, to reduce the warming of the soil and to keep humidity in the soil, until it eventually becomes an organic material that benefits the soil.

Composting is one of the few methods available to create a soil-like material on eroded land rapidly. Soil erosion has a direct financial impact on food production and on the economy and furthermore, eroded land can lead to pollution of surface water because of agricultural runoff from croplands.[165]

2.1. Wood and other types of biomass that can be recovered

Deforestation is a major problem accounting for up to 15% of GHG emisions. Although cutting down of primary forests is illegal, in many countries the problem continues as local communities use the wood for combustion and fuel. The alternative is to use wood waste or by-products from wood processing industries such as chips, bark and sawdust are used within sawmills and boardmills to provide heat for drying or space heating and to raise steam for the manufacturing process.[166]

Figure 29: Biomass energy by combustion (Heating/biodesel) and for composting
NB:Biomass can be converted into different forms of energy including heat, power, combined heat and power (CHP) or liquid biofuels.

165 www.fao.org/docrep/016/k1455e/k1455e.pdf.

166 www.fao.org/docrep/016/k1455e/k1455e.pdf.

Forest residue, consists mainly of treetops and branches which remain after timber is harvested. Some forest residue needs to be left on the forest floor to decompose and to return nutrients to the soil. This also allows the waste to act as brash mats, and to allow machinery to travel across soft ground.

However, a lot of this material could be harvested with suitable machinery and used as a renewable fuel for energy production.

There are a number of processes that can be used to recover energy from biomass fuels:[167]

a) **Direct combustion of biomass material** (to produce electricity). The heat, often in the form of steam, can be converted to electricity and/or it can be used for heating houses and buildings.

b) **Gasification and pyrolysis** are thermochemical processes (solid biomass is upgraded to a liquid or a gas). At its simplest, biomass is partially oxidised at high temperatures to produce biogas. This biogas contains a mixture of carbon monoxide, hydrogen and methane. The advantage of this process is that undesirable particulate matter and pollutants are removed. **Pyrolysis** is a mean of converting solid organic material into a liquid biofuel by heating at high temperatures in the absence of oxygen. The resulting pyrolytic or '**bio-oil**' can be refined to products in a manner similar to refining crude oil and can be used for electricity production in diesel engines. Pyrolysis oils are easy to transport and store.

c) **Anaerobic digestion**: Anaerobic Digestion (AD) converts Biomass to **biogas**. This is the breakdown of organic waste by bacteria in an oxygen-free environment. AD can take place in a specially designed AD plant or naturally at landfill sites. The waste/feedstock is placed in an airtight container (digester) along with bacteria. Depending on the waste and system design **biogas typically contains 55-75% pure methane**. This biogas can be upgraded to fossil ('natural') gas, which typically contains 70-96% methane. The liquid fraction of the remaining digested feedstock can be returned to the land as a fertiliser and solid fibre used as a soil conditioner.

d) **Fermentation**: Biomass is **converted to alcohol** by the process of fermentation. This is where bacteria convert carbohydrates in plant material from crops such as sugar beet and sugar cane into bioethanol.

- *Biomethanol is produced from a synthesis gas (a mixture of carbon monoxide and hydrogen)* that is derived from biomass sources such as crop residues, grasses, short rotation forestry and municipal forest waste through the process of gasification. Further research on aspects of synthesis gas production will help to make biomethanol production more cost effective.

167 www.seai.ie/uploadedfiles/RenewableEnergy/REIOBiomassFactsheet.pdf.

- *Biodiesel can be produced from different types of vegetable oils*: oils e.g. oilseed rape, sunflower oil, palm oil, soybean oil and waste vegetable oil. The oil is first pressed from plant material and then converted to biodiesel by a transesterification process. This process involves combining the oil with an alcohol in the presence of a catalyst. Costs of feedstock production can be high in some cases, but the use of waste vegetable oil offers a low cost alternative.

It is important to highlight that in rural ares across ACP countries, combustion of dry agriculture waste has been the most important method for heating and cooking.

Some examples of waste to energy projects are coverd in chapter 2 and available on the following Web sites:

- **Planete Energies**: www.planete-energies.com/
- **Fullwell Transform**: www.fullwelltransform.org
- **Union of Concerned Scientists**: www.ucsusa.org/clean-energy/increase-renewable-energy/biomass-energy-agriculture#.WbfygqpOelnergy

The table below illustrates the types of biomass product that can be obtained from different categories of plants.

Major category	Biomass feedstock
Forest products	Wood, logging residues, trees, shrubs and wood residues, sawdust, bark, etc
Bio renewable wastes	Agricultural waste, mill wood wastes, urban wood wastes, urban organic wastes
Energy crops	Short-rotation woody crops, herbaceous woody crops, grasses, forages crops
Food crops	Residue from grains and oil crops
Sugar crops	Sugar cane, sugar beets, molasses, sorghum
Landfill	Municipal solid waste
Industrial organic waste	Plastic wastes, oil wastes, leather wastes, rubber wastes, organic acid wastes, etc.
Algae, kelps, lichens, mosses	Water hyacinth, mushrooms, etc.
Aquatic plants	Algae, water weed, water hyacinth, reed, rushes

Figure 30: Major categories of biomass feedstock
Source: UE[168]

168 www.hia21.eu/dwnld/20131229_Waste%20management,%20waste%20resource%20facilities%20and%20waste%20conversion%20processes.pdf.

2.2. Case study of improved technologies using waste: Fullwell Mill[169]

There are a number of links between energy and food that can be utilized to improve energy access for smallholders. Fullwell Mill is for example converting mango waste into biogas, and the gas can then be used for fruit drying and cooking.

The process of improved solar tunnel dryers for pineapple and banana in Uganda also help to prevent post-harvest losses. Similarly, cashew shells can be converted to heat: only 25% of shell waste is sufficient for cashew cooking, steaming, and drying, which means that wood and butane are no longer necessary.

Fullwell Mill has replicated this system at three satellite women's Small and Medium sized Enterprises (SME) of cashew processors and supplies all their heating requirements. The other 75% excess of cashew shells results in other activities that require energy, for example: fruit drying, vegetable oil processing, bakeries and gasifier technologies adapted for small cashew SMEs.

2.2.1. What are improved and appropriatate technologies?

The term '**improved, appropriate technologies**' is a term that Fullwell Mill has given to summarise a variety of technology and equipment it has developed (either alone or in partnership with others) to improve the financial viability, energy reliability and sustainability, and environmental and even social impact of SMEs, especially agri-processors.[170]

Fullwell mill use **two kinds of technologies primarily:**

1. ***Energy generation using waste***, ideally from an SME's own operations, though it can also be from other waste streams available locally. There are times when it may be necessary to use non-waste fuels (e.g. firewood), where suitable waste streams are not available or economical. In the case of using firewood, the logic would be to reduce firewood use.

2. ***Improved drying systems***, where SMEs dry products, either using heat generated by waste or solar radiation, or combinations of both.

169 FM (www.fullwellmill.com/) is a UK-based food manufacturing business that is also an SME. It has been running for over 20 years and has a focus on manufacturing snack bars. It also has its own Fairtrade & Organic brand, Tropical Wholefoods (www.tropicalwholefoods.com).

170 Fullwell Mill - Energy + Appropriate Technologies work at SMEs.pdf.

The terms **improved and appropriate** are important, and are very relevant in relation to SMEs in developing and even emerging economies.

It means:

- Contributing to a number of advances over existing processes and equipment – principally, among others: quality and hygiene, increased capacity/production, ease-of-use, durability and reduced operating costs.[171]

- With an affordable upfront cost, and appropriate payback period. This influences the design and type of technology used, ensuring it is appropriate and affordable in the specific local context. The aim is to reduce entry-costs as far as possible while providing equipment that allows an operator to work at a viable scale while achieving the required product quality.

- Appropriate to the local landscape in terms of energy supply and usage, as well as available waste-streams.

- Is able to be manufactured and repaired locally using locally available materials, minimising reliance on importing parts and outside technical assistance.

- Is as easy to operate as possible, and robust.

2.2.2. Examples of innovative technologies

The most suitable technologies currently being applied for the ACP countries include:

- Gasification systems for energy generation.

- Drying systems using generated heat.

- Biogas systems for energy generation.

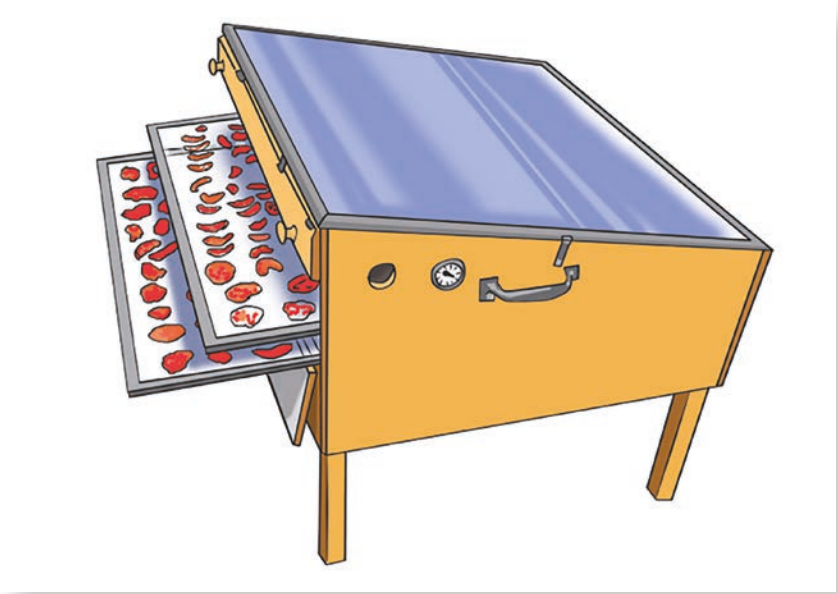
- Solar dryers (e.g. for pineapple and banana in Uganda) as illustrated below.

The solar dryer is a replacement of the conventional drying system (on the floor for example) as it protects better the crops from animals, insects, sun burning, dust, rain etc.[172]

It is a free and renewable source of energy, using the sun, and the fact that the product is enclosed in a solar dryer allows higher temperatures and a better quality and drying of the product.

171 http://e4sv.org/wp-content/uploads/2016/08/WR25-Smart-Villages-workshop-on-the-water-energy-and-food-nexus-Lessons-from-West-Africaweb.compressed.pdf.

172 www.fr.slideshare.net/e4sv/senegal-aug16-appropriate-energy-solutions-for-agrifood-processing-smes.

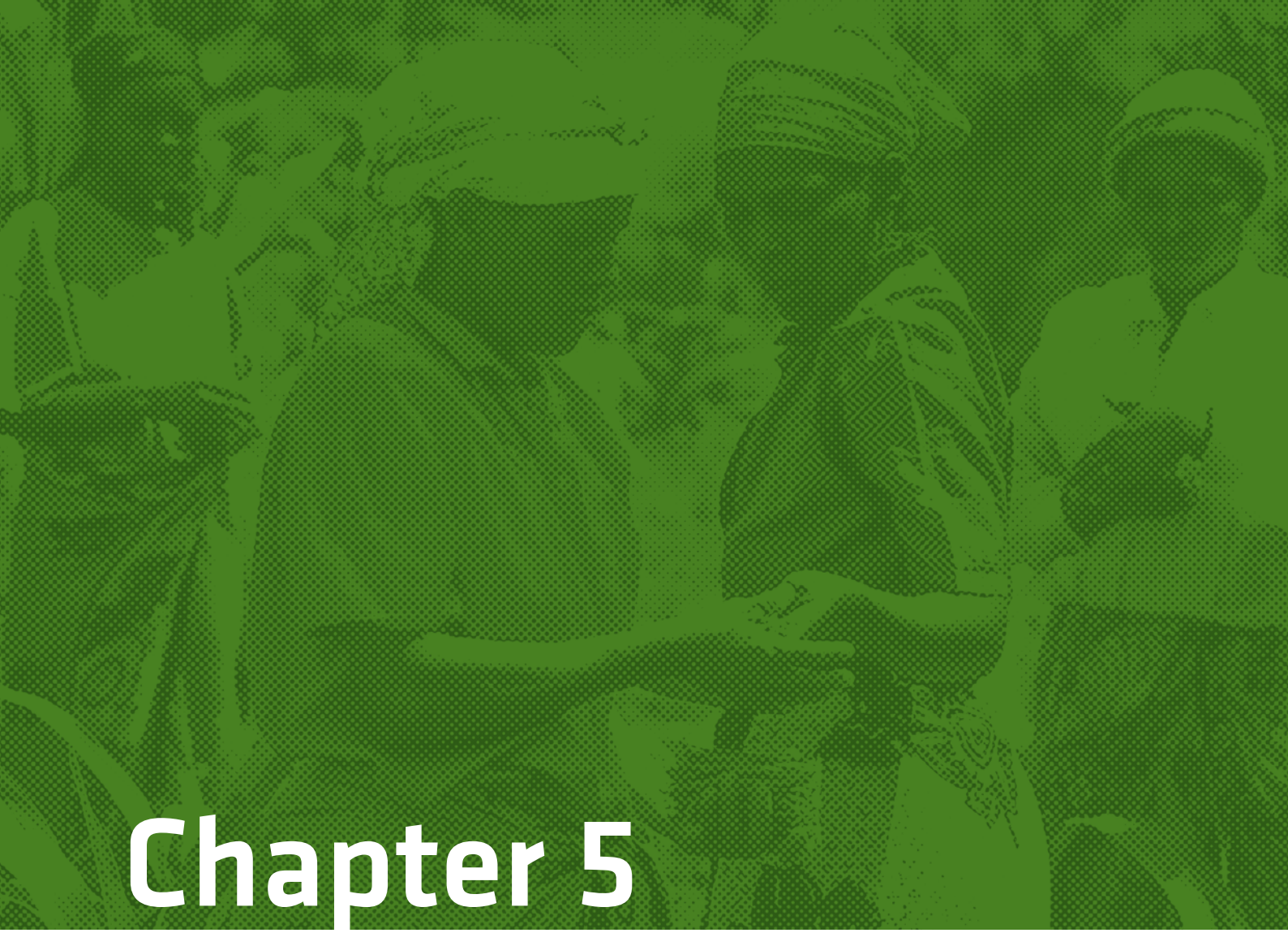


An example of a solar dryer

A solar dryer allows a better preservation of the crop as there will be not wastage and post harvest losses (the fruits will be dried and sold as so), the full crop can be used and the overall cost of the production can be lowered as the farmers will have diverse sources of revenue. Sun drying of crops is the most widespread method of food preservation in most part of the world because of solar irradiance being very high for the most of the year. As this technique needs no energy during day time, it is more beneficial to the small scale farmers who can't afford the electricity or other fuel for drying . A typical solar drier can process between 20kg and 150kg a day, depending on the size and product.

According to FAO solar dryer are better quality dryer as just letting the product left in the sun (less nutrient losses, no underisable physiological cahnges, better control of temperature and moisture).[173]

173 www.fao.org/docrep/x5018e/x5018E0v.htm.



Chapter 5

Treatment of waste

1. WASTEWATER TREATMENT

Water covers 71% of the surface of the world and is the main constituent of streams, lakes and oceans. Water can also be found in ice caps, in the air, in precipitation and on the ground. Only 2.5% of this is freshwater and an estimated 98.8% of freshwater is found in ice and groundwater. All in all, the world's rivers and lakes actually represent less than 0.3% of all freshwater and therefore are a precious resource that needs to be protected. According to the World Health Organisation (WHO), over 663 million people don't have access to safe drinking water, some 9% of the population.

Although the quantity of the world's water resource will never change, our production of wastewater is increasing with dramatic effects. Every year, two million tons of sewage and industrial/agricultural waste is discharged into the world's waterways, without taking into account illegal discharges. **Agriculture uses between 70% and 90% of the available freshwater, which then returns to the natural environment polluted**.

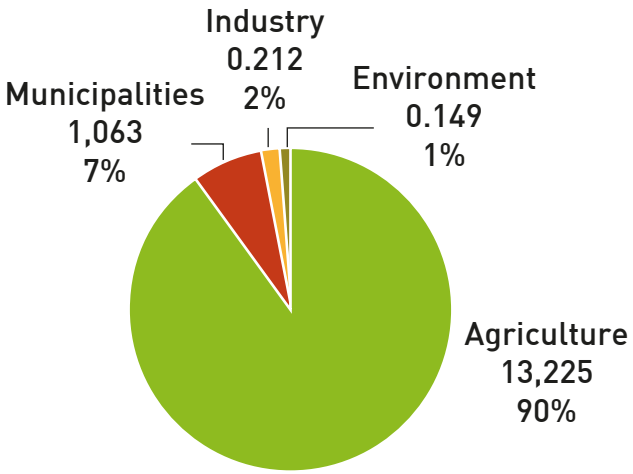


Figure 31: Fate of freshwater withdrawals: Global consumption and wastewater production by major water use sector (2010)
Source: FAO[174]

Human and industrial water consumption further drains freshwater resources, as shown on the graphic below. Over 80% of the world's wastewater – and over 95% in some least developed countries – is released to the environment without treatment.[175]

174 FAO, AQUASTAT (n.d.a.); Mateo-Sagasta et al. (2015); and Shiklomanov (1999). Contributed by Sara Marjani Zadeh (FAO).

175 www.greenfacts.org/en/wastewater-management/l-2/index.htm#0.

1.1. Minimizing the use and waste of water

With simple water saving measures and efficient methods of reusing and recycling water, we can cut freshwater use and reduce water pollution. In order to develop a more sustainable use of water, there are two parameters in which agriculture can have a major impact. The first is by **reducing water consumption. The second, is by treating and reusing wastewater**.

1.1.1. Reducing water consumption

The FAO estimates that an astonishing 60% of the water diverted or pumped for irrigation is wasted – via runoff into waterways or through evapotranspiration. By increasing efficiency in irrigation systems,[176] improved water management in agriculture could:

- Increase global water availability,
- Catalyse development,
- Reduce soil erosion, and
- Lead to increased and diversified agricultural yields,

Farmers can also achieve water-use efficiency gains in a number of ways:

i) By growing a diverse array of crops suited to local conditions, especially in drought-prone regions;

ii) By practicing agroforestry or growing perennial crops, to build strong root systems and reduce soil erosion;

iii) By maintaining healthy soils, either by applying organic fertilizer or growing cover crops to retain soil moisture;

iv) By adopting systems like drip irrigation that deliver water directly to plants' roots.

176 www.worldwatch.org/combat-scarcity-increase-water-use-efficiency-agriculture-0.

Drip irrigation systems for asparagus in Peru.
The crop is grown in sand and is waterfed directly with additional nutrients

1.1.2. Retaining water in the soil: Mulching

In arid regions of the Middle East, improved water management in agriculture has notably augmented both water and food security. An experimental drip irrigation project run by the Aga Khan Rural Support Programme in the Syrian village of Fraytan has, for example, reduced the annual demand for water by 30 percent and increased agricultural yields by nearly 60 percent.[177]

To **minimize the use of water on farm**, a solution is **to focus on drainage and the retention of water in the soil**, as well as **micro-evaporation**. A widely adopted method to keep water in soil is mulching.

Mulching consists of covering a surface of damaged land with organic matter (such as plants residues, straw, tree leaves) to encourage a reconstitution of the ground by maintaining humidity and developing a biologic activity (which produces carbon). The objectives of this method are to stimulate the organisms living in the ground, to protect the soil from erosion and dehydration, to improve infiltration and to raise the levels of humidity. The efficiency of the method in **reducing water evaporating from the ground** has been proved many times, and the heavier the mulch, the better the protection. Thanks to this, plants suffer less rapidly from loss of water during dry season and farmers can cut down on their water consumption. Mulching has been shown to reduce the surface temperature of crops during the day, thus protecting them and favouring their growth.

177 (www.irinnews.org/fr/node/248287)www.irinnews.org/fr/node/248287).

Mulching with dry leaves on a cocoa farm in Venezuela

Straw, corn residues, banana leaves can be used as mulch. Hedges residues must be cut into pieces measuring less than 10cm. mulch must be dispersed on the ground and covered in a thin layer of dirt to avoid being carried away by the wind. Mulch layers must not be too thick to avoid fermentation and the development of high temperatures.

In tropical regions, **plants that take longer to decompose are recommended**, to keep the ground covered longer[178] However, farmers must be careful to use discarded plant residues **where there is a risk that diseases can spread**. Only healthy plant leaves and branches should be used for mulching.

1.2. Treatment of wastewater

Wastewater may be defined as the combination of liquid wastes discharged from domestic households, farms, and institutions, commercial and industrial establishments eventually mixed with groundwater, surface water, and storm water.[178] The composition of wastewater varies widely and may contain:

- Pathogens such as bacteria, viruses, protozoa and parasitic worms;
- Organic particles such as faeces, hairs, food, paper, plant material;
- Inorganic particles such as salts, sand, grit, heavy metals, metal particles and ceramics;
- Pesticides and other toxins.

Depending on the contents and the toxicity, there are different methodologies for treating waste water and determining whether it can be reused. There are Waste water falls into 3 main categories, which are **Greywater, Black water, and Sewage**.

178 www.fao.org/docrep/016/i3041e/i3041e.pdf.

1.2.1. Greywater

This is used to describe slightly used wastewater that comes from sources such as the **shower rooms, the canteen and laundry**, either at the packhouse or the farm. It regroups most water that is used by humans for cleaning, except for toilet water. It can contain traces of food, grease, dirt, hair, and cleaning products.[179]

Treatment: As it can be used safely for irrigation and toilets, grey water **does not need to be treated**, or otherwise very lightly.

1.2.2. Blackwater (from the packhouse or farm)

This is principally wastewater that **comes from the toilet**, either at the packhouse or the farm

Treatment: It is difficult **to recuperate blackwater systematically**, according to the World Health Organisation, 40% of the world's population, approximately 2.5 billion people, does not have access to proper sanitation.[180]

1.2.3. Sewage (from the packhouse or farm)

Disposal affects people's immediate environments and if not treated properly, can lead to water-related illnesses. In developed countries, most people have flush toilets that take sewage waste quickly and hygienically away from their homes. Yet the problem of sewage disposal does not end there. When you flush the toilet, the waste has to go somewhere and, even after it leaves the sewage treatment works, there is still waste to dispose of. It has been known for sewage waste to be pumped untreated into the sea. Until the early 1990s, around 5 million tons of sewage was dumped by barge from New York City each year.

Treatment: In theory, sewage is a completely natural substance that should be broken down harmlessly in the environment, given that 90% of sewage is water. In practice however, **sewage contains all kinds of other chemicals, from the pharmaceutical drugs** that people take, to the **paper, plastic**, and other wastes they flush down their toilets. When people are sick with viruses, the sewage they produce carries those viruses into the environment. It is possible to catch illnesses such as hepatitis, typhoid, and cholera from river and sea water that has been contaminated from sewage.[181]

179 www.conserve-energy-future.com/ways-and-benefits-of-using-greywater.php.

180 World Health Organization (2015 and 2016).

181 Water pollution – An introduction to causes, effects, solutions.

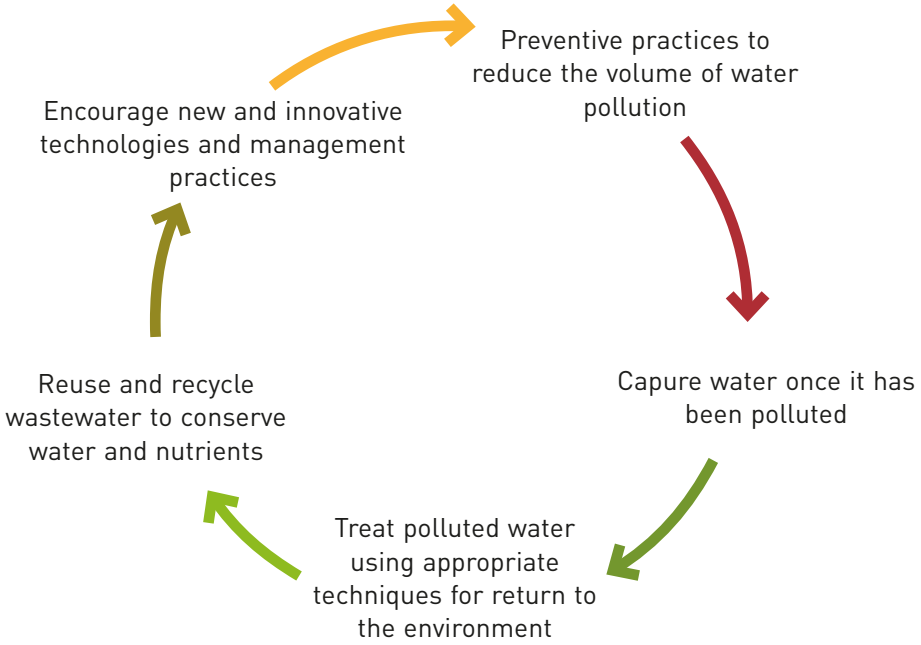


Figure 32: The virtuous circle of wastewater reduction and treatment
Source: Greenfacts[182]

1.3. Reusing water to reduce wastage

As the demand for water grows, so the more water is extracted, treated, and transported sometimes over great distances, which then requires a lot of energy. If the local source of water is ground water, **the level of ground water becomes lower as more water is removed and this increases the energy required** to pump the water to the surface.

Recycling water on site or nearby reduces the energy needed to move water longer distances or pump water from deep within an aquifer. **Tailoring water quality to a specific water use** also reduces the energy needed to treat water. The water quality required to flush a toilet is less stringent than the water quality needed for drinking water and requires less energy to achieve. Using recycled water that is of lower quality, for uses that don't require high quality water saves energy and money by reducing treatment requirements.

One way to save on water is through rainwater harvesting, which is the act of collecting rainwater in outdoor recipients and using this for irrigation or for use in sanitary installations such as the toilets, where no freshwater is needed.

182 www.greenfacts.org/en/wastewater-management/l-2/index.htm#0.

The same can also be done with 'grey water' which is used to describe semi-clean freshwater, which has been used in the canteen, in the showers or in the laundry room. The collection of grey water, can done using a manual system or an automated one, using sewage and piping. Both rainwater and grey water can be stored in containers. Even if it is best to use them within 24 hours after they were collected to avoid the accumulation of bad smells, by adding chlorine or iodine, it is possible to store water longer.[183]

There are many compelling reasons why farmers use wastewater for irrigation. This wastewater can come from the grey water at the packhouse, from leaks or just simply ground rainwater. Wastewater is a reliable supply of water that allows farmers to grow crops throughout the year. It also contains nutrients that can improve crop growth. Furthermore, it is often the only water available, so farmers especially in urban areas have no choice but to use this wastewater to irrigate their crops.[184]

A system for treating water at the packhouse or on the farm should include:

i) **Collection grey water used for cleaning fruits and for washing, showering:** the water can be collected through a drainage system and used for irrigation;

ii) **Development of preventative practices for contaminated water:** capture and separate water once it has been polluted;

iii) **Treatment of polluted water through filtering methods:** using appropriate techniques;

iv) **Reuse and recycling of grey water.**

1.4. Avoiding the pollution of water

1.4.1. Water pollution

Water pollution is caused when one or more substances have built up in water to such an extent that they cause problems for animals, the environment or people. Oceans, lakes, rivers, and other inland waters can naturally clean up a certain amount of pollution by dispersing it harmlessly. However, if the amount of substance is too concentrated, it cannot be dispersed and causes problems for the fauna and flora, as well as the human population.[185] The FAO, defines two types of water pollution:

183 www.conserve-energy-future.com/ways-and-benefits-of-using-greywater.php.

184 www.fao.org/docrep/016/i3041e/i3041e.pdf.

185 Water pollution – An introduction to causes, effects, solutions www.fao.org/docrep/w2598e/w2598e04.htm.

- **Non-point source water pollution**

Also known as 'diffuse' source pollution, it arises from a broad group of human activities for which the pollutants have no obvious point of entry into receiving watercourses.[186]

- **Point source pollution**

This results from the activities where wastewater is routed directly into receiving water bodies through obvious channels, for example, discharge pipes, where they can be easily measured and controlled. Obviously, non-point source pollution is much more difficult to identify, measure and control than point sources.[187]

1.4.2. Key Sources of agricultural pollution[188]

The introduction of modern agricultural practices and intensive farming have led to agricultural pollution on a large scale. Indeed there are many causes to the agricultural pollution, including:

- Pesticides and fertilizers: They do not disappear easily. The soil, plants and animals are ingesting those products and therefore they are always found in the ground.

- Contaminated water used for irrigation: Even in cases where care has been taken to avoid pollution. In many cases, there are heavy metals, pesticides, and other organic compounds polluting water as a result of industrial and agricultural waste in the ground or in local bodies of water.

- Soil erosion and sedimentation: Soil is comprised of many layers and it is only the topmost layer that can support farming. Due to inefficient farming practices the soil is left open for erosion and leads to declining fertility each year. Whether eroded by water or wind, all the soil has to be deposited somewhere or other. The resulting sedimentation causes soil build up in areas such as rivers, streams, ditches and surrounding fields. And so the process of agricultural pollution prevents the natural movement of water aquatic animals and nutrients to other fertile areas.

186 *Ibid.*

187 *Ibid.*

188 www.en.wikipedia.org/wiki/Agricultural_pollution.

- Livestock: Before the industrialisation of agriculture farmers would keep as much livestock as their land could support. All animals were fed natural diets, supplemented by the waste left over from the crops. As a result the animals were contributing to keeping the farm healthy. But nowadays, livestock is grown in cramped conditions and fed with non-natural diets. As such, they contribute to the process of agricultural pollution.

- Pests and weeds: When farmers grow local species, they are adapted to the land and to the local biodiversity. Today growing exotica and /or non adapted species adds to the pollution as the natural species the native population has to deal with new deceases pest and weeds that is it not capable of fending off, hence the use of pesticides and herbicides.

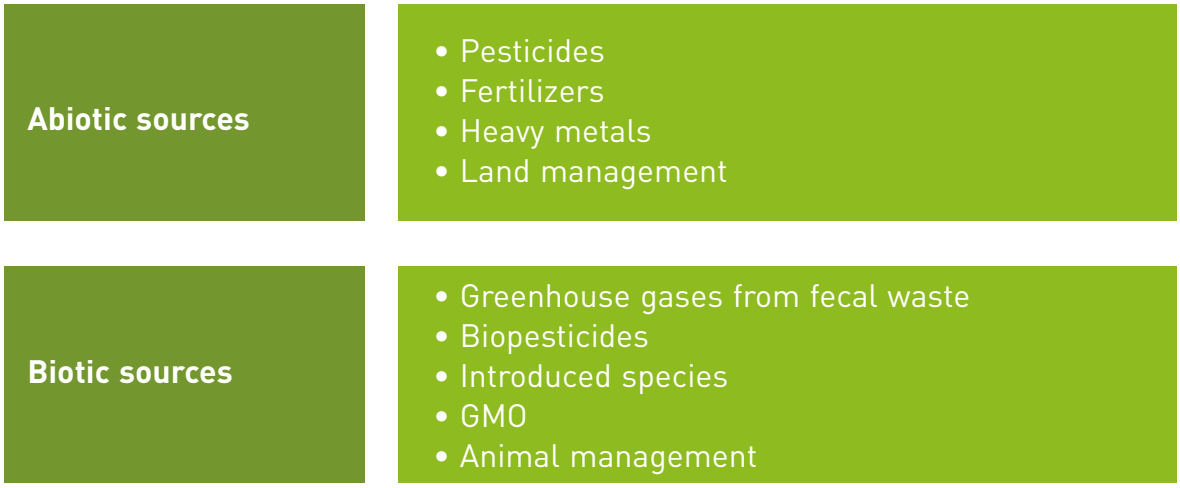


Figure 33: Abiotic and biotic sources of agricultural pollution

1.5. Agricultural impacts on water quality

1.5.1. Agricultural activities leading to water pollution

The table below highlights some of the most common sources of water pollution within agricultural activities, the impacts on surface water and groundwater and the types of measures that can be taken to control water pollution.

Agricultural activity	Impacts		Measures that can be taken to control water pollution
	Surface water	Groundwater	
Tillage/ Ploughing	**Sediment/turbidity:** sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.		Use buffer strips and other measures to reduce surface run-off from fields.
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth leading to deoxygenation of water and fish kills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health.	Maintain a suitable distance from any watercourse including ditches (e.g. an estimated 10m) or drinking water supplies (e.g. an estimated 50m), especially when handling or applying fertilisers, organic wastes, pesticides or other chemicals.
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	Contamination of ground-water, especially by nitrogen	Manure should be stored in a covered area to maintain it's quality. This should be stored a suitable distance from any watercourse including ditches (e.g. 10m) or drinking water supplies (e.g. 50m), especially when handling or applying fertilisers, organic wastes, pesticides or other chemicals.

Phytosanitary products	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems 1000s of miles away	Some pesticides may leach into groundwater causing human health problems from contaminated wells.	Account for every input, especially of nutrients, pesticides and other chemicals through rational use planning. Develop integrated pest management systems. Applicators should be trained on the correct use of pesticides. They should read the labels warning of the risk of pesticide leaching, under environmental hazards. The presence of field drains may allow diffuse pollutants to by-pass a buffer strip, and intercepting the drains might be the only way to achieve a significant reduction in risk. In certain cases, intercepting drains could result in the creation of wetlands or ponds. Obtain specialist advice when considering using wetlands, ponds or infiltration systems to treat contaminated roof or dirty yard run-off at the farm steading.
Feedlots/ Animal corrals	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.	Potential leaching of nitrogen, metals, etc. to groundwater.	Minimise the area of farmyard and roads over which animals can excrete and over which equipment transporting slurry is moved. Take steps to control the run-off from these areas. Don't allow livestock to have access to watercourses. Instead, provide water at drinking troughs wherever possible.

Irrigation	Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.	Enrichment of groundwater with salts, nutrients (especially nitrate).	Proper irrigation management is critical to minimize the risk of pesticides moving to groundwater. Care should be take to ensure that Irrigating saturated soils or irrigating at a rate that exceeds infiltration rate of soil does not promote runoff that can carry pesticides with it. Soil structure needs to be analysed to test its ability to filter water. Eg. coarse-textured soils need more irrigation and there is increased risk.
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.	Disruption of hydrologic regime, often with increased surface runoff and decreased groundwater recharge; affects surface water by decreasing flow in dry periods and concentrating nutrients and contaminants in surface water.	Soil erosion on susceptible fields can be minimised by using minimum tillage systems, diversion systems and grass buffer strips, and also by adapting field activities according to local risks. Cultivated soils which are light textured should not be left without a crop or stubble cover during the autumn and winter period.
Forest areas can be useful for control of polluted water	Broad range of effects: pesticide runoff and contamination of surface water and fish; erosion and sedimentation problems.		Develop a small green belt around the areas where there is risk of run off using an agroforestry system eg. planting trees with high transpiration rate (“thirsty” trees) such as eucalyptus. These can be easily used to clean the environment of wastewater. However, care must be taken for these to be small buffers. Eucalyptus have long been blamed for their “thirst” for ground water, owing to their long tap roots, and could dry up water bodies if they are planted in too large a volume.

Aquaculture	Release of pesticides and high levels of nutrients to surface water and groundwater through feed and faeces, leading to serious eutrophication. Eutrophication of waters is the phenomenon of an ecosystem becoming more productive by nutrient enrichment, stimulating primary producers. It is usually characterized by algal blooms, causing water quality deterioration and fish kills.		Aquatic treatment systems consist of one or more shallow ponds in which one or more species of water tolerant vascular plants such as water hyacinths or duckweed are grown

Figure 34: Agricultural activities leading to water pollution

1.5.2. How to stop water pollution on farms

There are clear benefits to reducing water pollution on a farm. These can have a significant impact on costs of production. The following should be considered:[189]

- **Watershed efforts:** collaboration of a wide range of people and organizations to reduce pollution. This is relatively cost effective, but requires buy in from a large number of stakeholders.

- **Nutrient management**: apply fertilizers in the right amount, at the right time and with the right method. This can result in cost savings, if and when the right amount of nutrients are measures.

- **Cover crops:** keep nutrients out of the water by recycling excess nitrogen. Relatively cost efficient measure that does not require an important monetary investment.

- **Buffers:** can help absorb or filter out nutrients before they reach water channels. Also a cost effective measure, although it will require labour.

- **Conservation tillage:** a reduction of the number of times fields are tilled reduces erosion, soil compaction and runoffs, and builds soil organic matter. This is cost effective given that manhours are reduced, with less people required to carry out the tillage.

189 www.epa.gov/nutrientpollution/sources-and-solutions-agriculture.

- **Managing livestock waste:** keep animals and their waste out of streams, rivers and lakes to keep nitrogen and phosphorus out of it. There are two options: a) to fence the farm area man hours and materials are needed b) if it is a large farm, it may be more cost effective to create a fenced living area for the animals.

- **Drainage water management:** reduce nutrient loadings that drain from agricultural fields to help prevent degradation of the water in local streams and lakes. Through the introduction of water filtration ponds, this could be a relatively inexpensive system to apply. The image below was inspired by Rainforest Alliance training material.

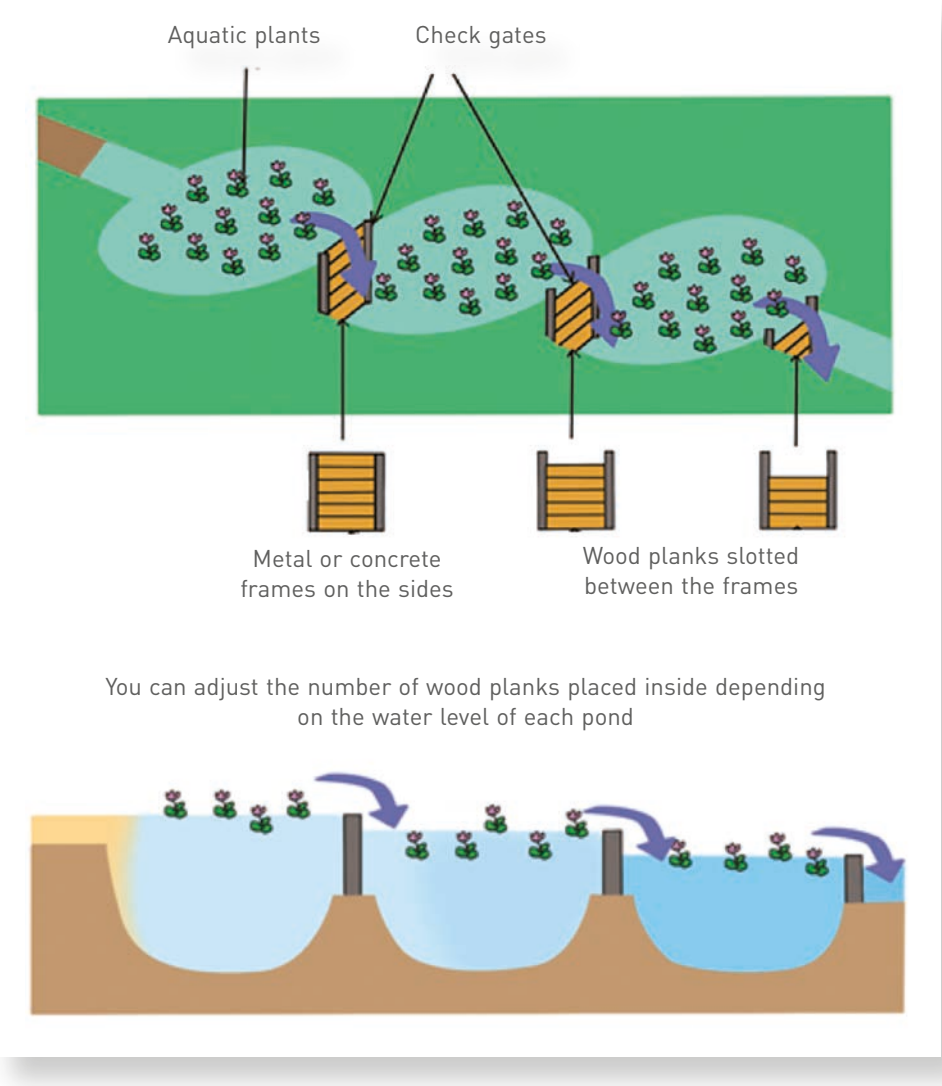


Figure 35: Using aquatic plants to clean water

Example of 3 lagoons with aquatic plants. System adapted for :
- a very large volume of waste water
- a site with a slight slope
- a site with a large area available for a water treatment system

1.6. Hierarchical complexity of agriculturally-related water quality problems

Non-point source pollutants, irrespective of where they come from, are transported overland and through the soil by rainwater and melting snow. These pollutants ultimately find their way into groundwater, wetlands, rivers and lakes and, finally, into oceans in the form of sediment and chemical loads carried by rivers.

The ecological impact of these pollutants range from simple nuisance substances to severe ecological impacts involving fish, birds and mammals, as well as human health. The range and relative complexity of agricultural non-point source pollution are illustrated in the figure below.

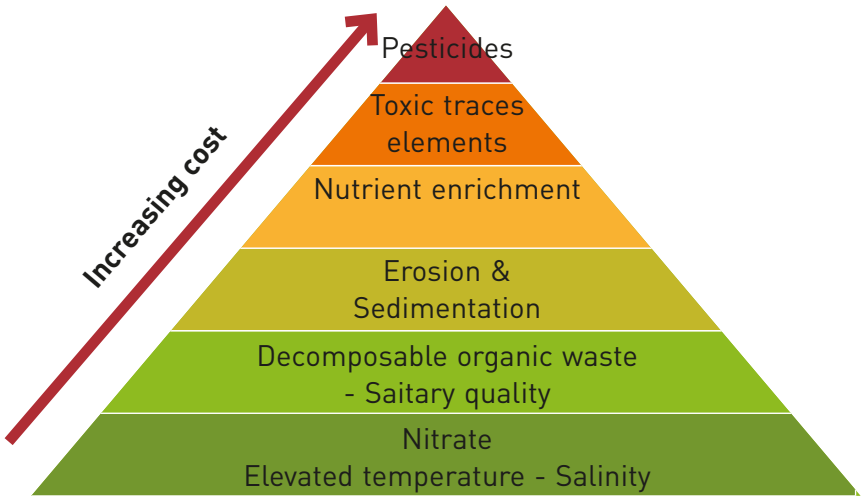


Figure 36: Hierarchy of water pollution and problems
Source: FAO[190]

1.7. Addressing water pollution in the horticultural industry

According to the FAO, there are 3 key areas of intervention in order to stop water pollution. These are embedded in Education, Legislative and Economic frameworks:[191]

i) **Education:** making people aware of the problem and educating them about the causes and effects of water pollution, and the advantages of reusing it within safe parameters.

ii) **Legislation:** this is essential to control water pollution at a global scale and to transcend borders between countries. Examples of international laws which aim to control water pollution are:

- 1982 UN Convention on the Law of the Sea (signed by over 120 nations)
- 1972 London (Dumping) Convention

190 www.fao.org/docrep/w2598e/w2598e04.htm.

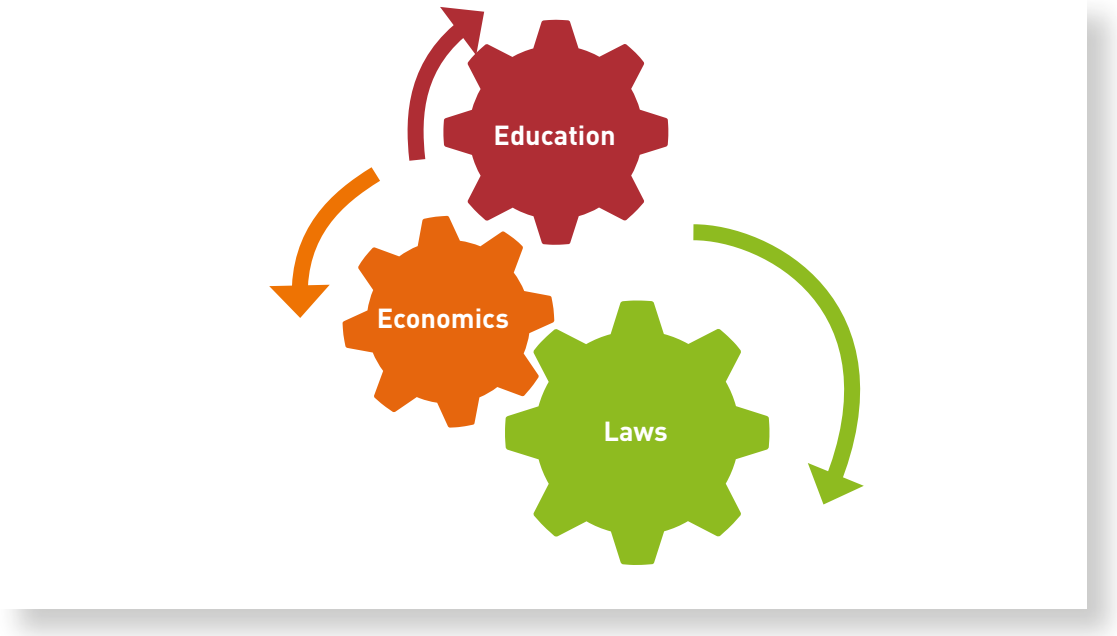
191 Water pollution – An introduction to causes, effects, solutions www.fao.org/docrep/w2598e/w2598e04.htm.

- 1978 MARPOL International Convention for the Prevention of Pollution from Ships

- 1998 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic

Most countries also have their own national legislation to protect water.

iii) **Economic:** numerous environmental experts agree that the polluter pay principle (which means the entity responsible for the pollutions has to pay for cleaning it up) is one of the best ways to reduce pollution. This principle means that those who pollute have to pay extra charges, and is an incentive to reduce pollution at a small, local scale as well as a national one. It is applied in many countries and regions of the world, such as Europe for instance.



1.8. Collecting and improving reusable water

1.8.1. Waste water collection

Waste water can be collected from the packhouse and from the farm **in 3 ways**[192] :

- Through manual collection.

- Through a simple piping or plumbing system: establishing connections between the washing area wastewater drain pipe and the lawn.

192 www.conserve-energy-future.com/ways-and-benefits-of-using-greywater.php.

- Through integrated sewage and pumping: a system that connects the factory floor, the canteen area, the showers and the bathroom drains to a system that dispenses grey water into a collection tank.

To purify grey water or wastewater, filters can be used. For instance, at the Songhaï farm in Benin, everything is reused or recycled, and wastewater is not an exception. Grey water is stored and used for irrigation. Blackwater is filtered through hyacinths and serves for the fish (See case study in section 4.1.4).

1.8.2. A possible use for recycled grey water from the farm: create and enhance wetlands and riparian habitats.

Wetlands provide many benefits, which include wildlife and wildfowl habitat, water quality improvement, flood diminishment, and fisheries breeding grounds.

For streams that have been impaired or dried from water diversion, water flow can be augmented with recycled water to sustain and improve the aquatic and wildlife habitat.

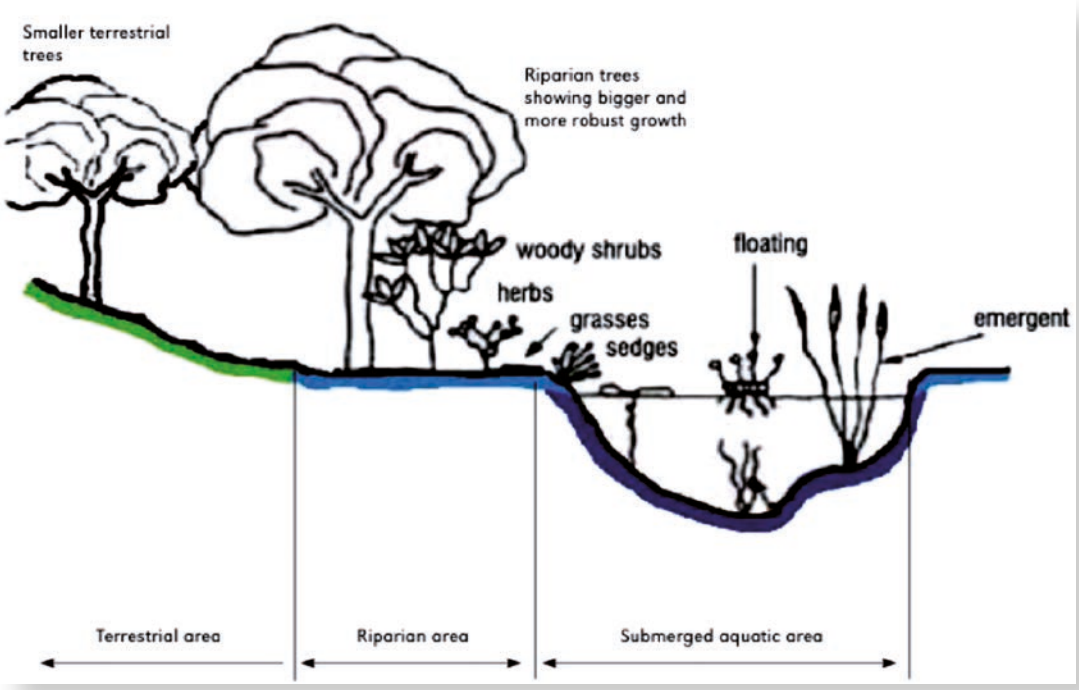


Figure 37: Typical cross section of a river channel
Source: Biodiversity Advisor[193]

Many riparian areas display wetland indicators and should be classified as wetlands. However, other riparian areas are not saturated long enough or often enough to develop wetland characteristics.

193 http://biodiversityadvisor.sanbi.org/wp-content/uploads/2016/07/DWS-wetland-delineation-manual.pdf.

Riparian areas perform a variety of functions that are of value to society, especially the protection and enhancement of water resources, and provision of habitat for plant and animal species.

Riparian areas have multiple benefits, namely:

- storing water and help reduce floods ;
- stabilizing stream banks;
- improving water quality by trapping sediment and nutrients;
- maintaining natural water temperature for aquatic species;
- providing shelter and food for birds and other animals;
- providing corridors for movement and migration of different species;
- act as a buffer between aquatic ecosystems and adjacent land uses.

1.9. Recycling water to save energy

The 2005 report California's Water – Energy Relationship (by the California Energy Commission) highlights the large amount of energy required to treat and distribute water, a process shown below:

Although it requires additional energy to treat wastewater for recycling on site, it is still less than the amount required to extract and distribute it.

There is no doubt that non-potable reuse is a widely accepted practice that will continue to grow. However, in many parts of the world, the uses of recycled water are expanding to accommodate the needs of the environment and growing water supply demands.

Advances in wastewater treatment technology and health studies of indirect potable reuse have led many to predict that planned indirect potable reuse will soon become more common, as recycling waste and grey water requires far less energy than treating salt water using a desalination system. The latter has long been considered

as a key option for treating salinated water for the horticultural industry in the long term.[194]

While water recycling is a sustainable approach and can be cost-effective in the long term, the treatment of wastewater for reuse and the installation of distribution systems at centralized facilities can be initially expensive compared to such water supply alternatives as imported water, ground water, or the use of greywater onsite from packhouses and farms. Institutional barriers, as well as varying agency priorities and public misperception, can make it difficult to implement water recycling projects.[195]

Overall, **water recycling has proven to be effective** and successful in creating a new and reliable water supply without compromising public health.

For horticultural producers, required to have Good Agricultural Practice (GAP), the FAO has a specific section on recycling of water on the farms.[196] It asks producers to:

- Practice scheduled irrigation, with monitoring of plant needs, and soil water reserve status to avoid water loss by drainage.
- Prevent soil salinization by limiting water input to needs, and recycling water whenever possible.
- Avoid crops with high water requirements in a low availability region.
- Avoid drainage and fertilizer run-off.
- Maintain permanent soil covering, in particular in winter to avoid nitrogen run-off.
- Manage carefully water table, by limiting heavy output of water.
- Restore or maintain wetlands.
- Provide good water points for livestock.
- Harvest water in situ by digging catch pits, crescent bunds across slope.

194 Redouane, Choukr-Allah "The Souss-Massa River Basin, Morocco" 2017, Springer International Publishing.

195 www.www3.epa.gov/region9/water/recycling/#diversion.

196 www.en.wikipedia.org/wiki/Good_agricultural_practice.

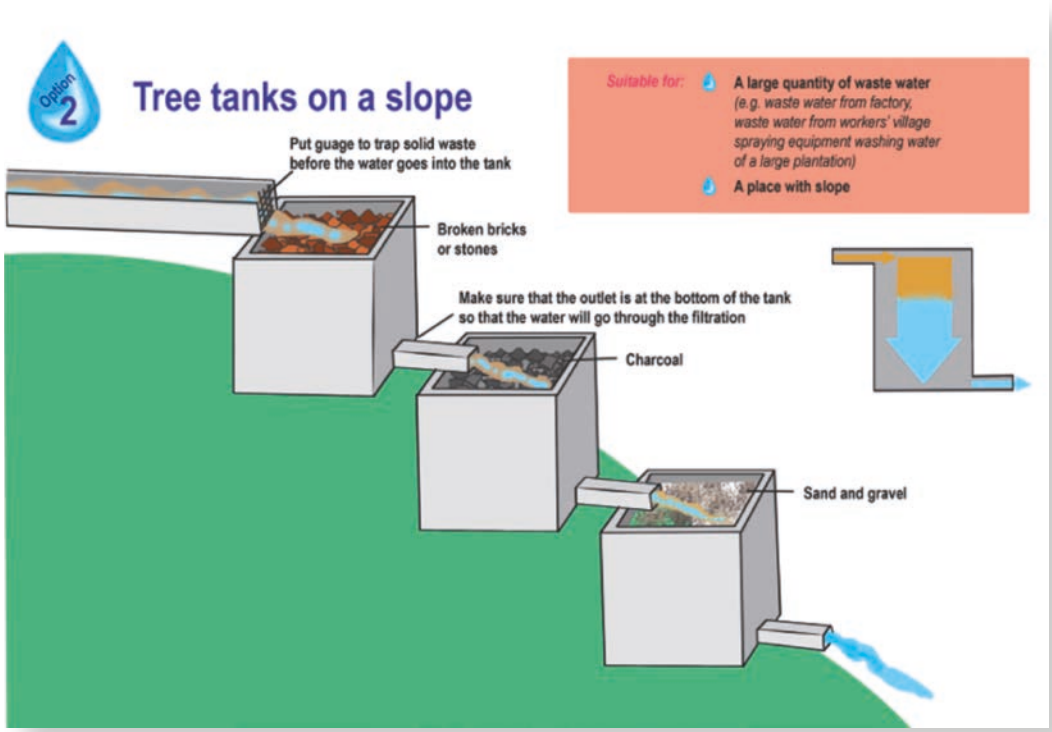


Figure 38: Water filtration system from a packhouse.
System suitable for:
- a large volume of wastewater (e.g., wastewater from a factory, wastewater from the washing water from the spraying equipment of a workers' village on a large plantation)
- a site with a slope

1.10. Case study: Fullwell Mill technology for treating organic waste and grey water produced by SMEs

Fullwell Mill are implementing additional technologies for treating organic waste and grey water produced by SMEs, including composting, anaerobic baffle reactors and water filters.

An Anaerobic Baffled Reactor (ABR) is an improved septic tank because of the series of baffles over which the incoming wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment.

The majority of settle able solids are removed in the sedimentation chamber at the beginning of the ABR, which typically represents 50% of the total volume. The up-flow chambers provide additional removal and digestion of organic matter: BOD may be reduced by up to 90%, which is far superior to that of a conventional septic tank.

Advantages[197]

- Resistant to organic and hydraulic shock loads
- No electrical energy required
- Grey water can be managed concurrently
- Can be built and repaired with locally available material
- Long service life
- No real problems with flies or odours if used correctly
- High reduction of organics
- Moderate capital costs, moderate operating costs depending on emptying; can be low cost depending on number of users

Disadvantages

- Requires constant source of water
- Effluent requires secondary treatment and/or appropriate discharge
- Low reduction pathogens
- Requires expert design and construction
- Pre-treatment is required to prevent clogging of the pipelines..

The waste water is transported through pipelines from the point of departure to the reactor.

197 www.waste.nl/sites/waste.nl/files/product/files/treatment.pdf.

2. HAZARDOUS WASTE TREATMENT

2.1. Identifying and classifying hazardous waste

Simply defined, a hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes, phytosanitary products to batteries and may come in many forms, including liquids, solids gases, and sludges.[198]

2.1.1. Nature of hazardous wast

Hazardous waste streams on farms **based on frequency of use include:**

- Fertilizers, pesticides and chemicals;
- Hormone or plant growth regulators;
- Veterinary pharmaceuticals;
- Fumigants;
- Used oil filters;
- Polychlorinated Biphenyls (PCBs) PCBs (present in pesticides) are recognised as a threat to the environment due to their toxicity, persistence and tendency to build up in the bodies of animals;
- Fluorescent tubes;
- Brake fluid;

198 www.epa.gov/hw/learn-basics-hazardous-waste.

- Waste paint and thinners;
- Batteries (lead acid, Ni-Cd and mercury);
- Some printer toner cartridges;
- Asbestos waste;
- Clinical waste.

The World Health Organisation (WHO) has classified materials based on the severity of the hazard, which it may cause.[199] These are:

- Extremely hazardous
- Highly hazardous
- Moderately hazardous
- Slightly hazardous

Toxicity: cyanide solutions / waste pesticide – can be harmful or fatal when ingested inhaled or absorbed through the skin

Corrosivité: acids from metal cleaning processes /liquor from steel manufacture – acids or alkalis can dissolve human flesh or corrode metal.

Ignitability: waste oil, solvents organic cleaning material paint waste – are highly combustible substances and a potential fire hazard if not disposed of adequately. **(poor mixture or misuse of the material can have a fatal effect):** peroxide solutions hypochlorite solutions or solids – can cause explosion and toxic fumes in the event of an explosion. Oils, soluble salts can be harmful or deadly to other species or to the ecological integrity of their habitat.

It is important to know if they are ignitable, corrosive, reactive, toxic, poisonous or Eco toxic. The illustrations below, show some of the signages that often accompany hazardous materials.

199 www.moe.gov.jm/sites/default/files/Management%20of%20Hazardous%20Material%20and%20Waste.pdfUnlikely to present acute hazard in normal use.

Figure 39: The different signs of hazardous products
Source: Toddskips[200]

2.1.2. Methods of hazardous waste classification

Generally speaking, different types of hazardous wastes are classified by their chemical, biological and physical properties:

- **Inorganic wastes:** e.g. acids, alkalis, heavy metals, cyanides, wastewaters from electroplating;
- **Organic wastes:** e.g. pesticides, halogenated and non-halogenated solvents, PCBs;
- **Oily wastes:** e.g. lubricating oils, hydraulic fluids, contaminated fuel oils;
- **Sludge:** e.g. from metal working, painting, wastewater treatment.

2.1.3. Examples of Hazardous waste legislation in African countries[27]

There is increased recognition globally that disposal of hazardous waste must be done in a responsible manner. There are 2 pieces of legislation in Africa which act as a framework for the safe disposal of hazardous waste. For example:

- **Kenya.** According to EMCA (1999) it is the responsibility of the generators of hazardous waste to manage their waste. Management of hazardous waste particularly POPs are being addressed by domesticating the Stockholm Convention. The Government of Kenya banned the importation and use of pesticides containing aldrin, chlordane, dieldrin, endrin, heptachlor, HCB, mirex and toxaphane. According to records of the Pesticide Control Products' Board (PCPB), no pesticide POPs have been imported into the country since 2001. However, some may have found their way into the country illegally.

200 www.toddskips.co.uk/tag/hazardous-waste/.

- **Zambia.** The Hazardous Waste Management Regulations Statutory Instrument No. 125 of 2001 provides for the control of hazardous waste so that the waste is managed in an environmentally sound manner through waste prevention, reduction, recycling, incineration and landfilling. The regulations further provide for control of generation, collection, storage, transportation, treatment, import, export and internal disposal of hazardous waste. The management of hazardous waste follows the provisions of the Basel and Bamako Conventions. (More information on the Bamako Convention is given in Chapter 1).

2.2. Limiting hazardous waste

The following are examples of how to minimise and limit hazardous waste in the production process in horticulture.

2.2.1. Limiting hazardous waste on a farm

Where disposal of hazardous wastes presents a challenge, the preferred solution is to:[201]

- Purchase only the required amount of hazardous material, which can be used before the expiration date of such material;
- Use the hazardous material only for the purpose intended;
- Determine if someone else in the institution or community has a legitimate need for and can use any excess material;
- Composting and using compost instead of fertilizer sorting as much as possible on site.

2.2.2. Options for reuse/recycle/sell/give/throw

Hazardous Waste must not be thrown away, put into the soil, on the ground, in local landfills not equipped for them, in septic tanks, in open burning landfills. They can contaminate the water, the soil and therefore the crops and the health of the people.

The waste must be either:

- Disposed in adequate and controlled disposal places and taken care by appropriately licensed agencies, or
- Disposed in an incineration facility with adequate environmental controls for air emissions and ash treatment, or

201 www.moe.gov.jm/sites/default/files/Management of Hazardous Material and Waste.pdf.

- Recycled or reused whenever it is possible (for example the oil used in the machinery can be used to treat the wood in the farm, in place of terebenthine essence).

When the options above are not possible, it is recommended that the hazardous waste is stored until a proper solution can be found for its safe disposal.

2.3. Case study of hazardous waste management in Egypt[202]

In Egypt, a hazardous waste landfill (Nasiriya) was constructed with financial support from the Government of Finland. It receives hazardous waste from all over the country. It is the first central general hazardous waste treatment and disposal facility in Egypt.

The operational procedures in place enable the tracing of waste within the facility from the point of acceptance until its final disposal in one of the cells of the landfill. A waste acceptance policy was developed for the landfill that includes general specifications about the chemical and physical properties of waste to be accepted, as well as lists of waste types and/or streams that satisfy such general specifications.

Treatment processes carried out at the initial phase of operation of Nasreya entail physical treatment through solidification in solar evaporation ponds followed by burial of the waste in a secure landfill. Subsequent stages of operation entail other physical treatment (such as solidification in cement blocks) as well as chemical treatment. Recently, the Egypt Environmental Affairs Agency licensed one of biggest cement companies, the Egyptian Cement Company (ECC), to accept and incinerate some combustible organic hazardous wastes in its cement kilns.

ECC will however remain primarily a cement plant and not a waste treatment or a recycling plant. Consequently, addition of sorting, treatment or recycling units for wastes is not in the plan of the company. The company uses the waste as an alternative fuel in its kilns and the high temperatures therein ensure effective destruction of the combustible organic chemical wastes.

202 Saad, 2009 http://www1.uneca.org/Portals/sdra/sdra3/chap4.pdf.

3. FINAL WASTE TREATMENT

It is important to understand that for responsible waste treatment all the parties have to work together in order to achieve waste reduction. Waste treatment must be handled between the farmers, governments, local associations and municipalities. We have seen that farmers can reuse some of the grey water, they can also reduce their needs in water which will be less costly for them and mean more water is available for the community. In terms of cost and employment, we have seen that recycling, reusing and composting generate employment and lower the costs of a farm, by reducing the amount of fertilizers purchased but also generating income by selling compost, plastic, glass or metal to recyclers.

An example of a national and farm **specific Integrated Waste Management Plan** (IWMP)[203] is covered in Chapter 2. The IWMP addresses all waste streams and sources and covers the full life cycle of each waste including reduction and segregation at source, collection, recycling, recovery and disposal. Application of various economical, efficient, cost effective and environmentally friendly waste recovery techniques and technologies should be adopted as ways of disposing wastes. Proper structures should be created to collect data on types, sources and composition of wastes to enable planning and investment and independently monitor and evaluate achievements.

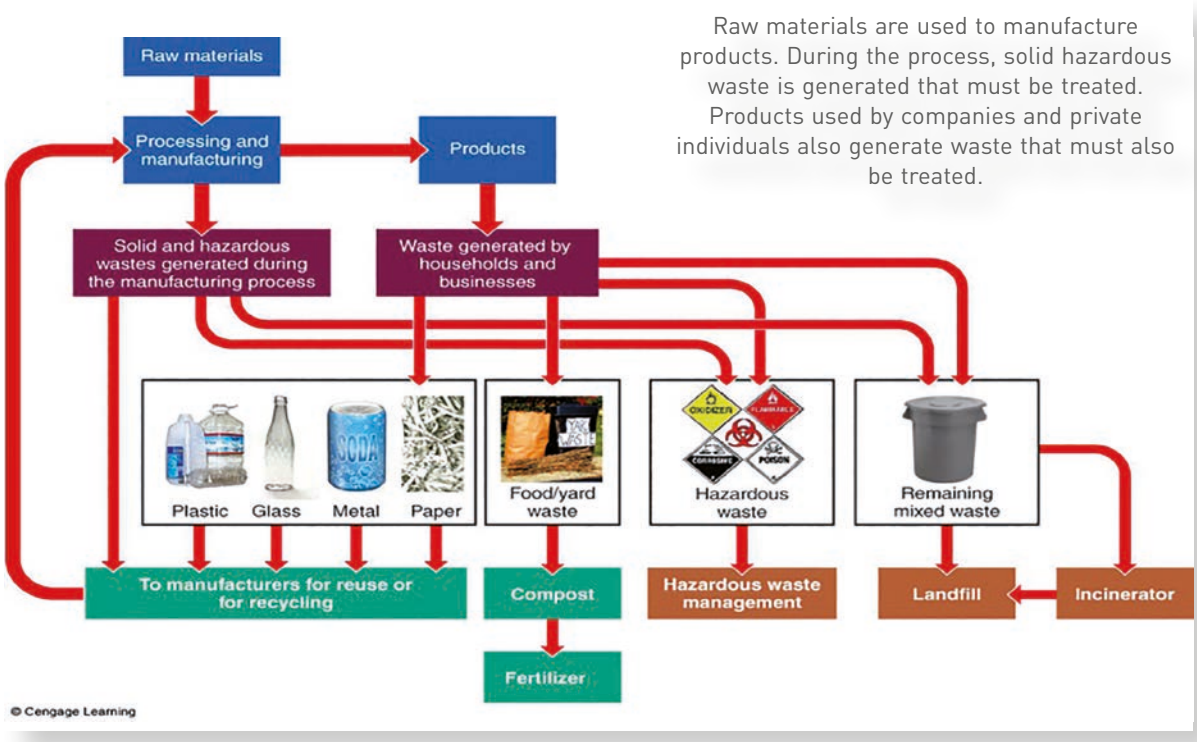


Figure 40: Considerations for responsible waste treatment
Source: Cengage[204]

203 http://www1.uneca.org/Portals/sdra/sdra3/chap4.pdf.

204 http://blog.nus.edu.sg/singapore2100/category/sustainability/solid-waste-management/.

A part of the waste is recycled, a part composted and will provide fertilizer. Another part is not recoverable (hazardous waste) and a part will go to the incinerator and landfill.

Authorities and private partners should charge appropriately for waste collection. This can encourage the private sector and enable NGOs to initiate new projects. The efficiency of waste collection and transportation can often be improved. Investments are needed to bring in more collection trucks that are appropriate to the composition of various waste streams in Africa.

Appropriate incentives can promote the usage of recycled, recyclable and/or biodegradable items for daily use, or the reuse of agriculture waste as a source of energy. Further recycling and re-use of waste can be promoted through the creation of regional networks. Disposing of wastes should be carried out in controlled landfills to prevent any contamination of water and soil.

3.1. Types of non-reusable waste and their disposal

Co-disposal of hazardous and medical waste with general waste should be avoided. For public health reasons it is especially essential that medical waste receives adequate treatment. Other examples of non-reusable waste are:[205]

- Waste oils and filters;
- Plastic containers from pesticide containers;
- Unwanted tires (unless used to create furniture);
- Seed and fertilizers bags;
- Obsolete pesticides.

According to the waste management hierarchy, landfilling is the least preferable option and should be limited to the necessary minimum. Safe disposal of these types of wastes can take place in:

- Incineration plants, which must have the correct permits to ensure safe disposal. These incineration operations will function from 700 to 1000 degrees.
- Co-incineration plants (such as cement or limekilns, steel plants or power plants whose main purpose is energy generation or the production of material products and in which waste is used as a fuel or is thermally treated for the purpose of disposal).

205 www.intechopen.com/books/integrated-waste-management-volume-i/waste-to-energy-wasting-resources-and-livelihoods.

- Specific landfills for hazardous or inert waste.

- Further information on incineration plants are available at PATH (Editor) (2010): *The Incinerator Guidebook. A Practical Guide for Selecting, Purchasing, Installing, Operating and Maintaining Small-Scale Incinerators in Low-Resource Settings*.

The poster below, highlights the key risks around hazardous wastes. It is part of an education campaign.

3.2. Waste for landfill

Where waste needs to be landfilled, it must be sent to landfills, which comply with the requirements of Directive 1999/31/EC on the landfill of waste (this applies in EU).[206] LThe objective of the Directive is to prevent or reduce as far as possible negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.

The Landfill Directive defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land. Landfills are divided into three classes:

- Landfills for hazardous waste;
- Landfills for non-hazardous waste;
- Landfills for inert waste.

A **standard procedure** for the acceptance of waste in a landfill is laid down so as to avoid any risks, including:

1. **Waste must be treated before being landfilled**;
2. Hazardous waste within the meaning of the Directive must be assigned to a hazardous waste landfill;
3. Landfills for non-hazardous waste must be used for municipal waste and for other non-hazardous waste;
4. Landfill sites for inert waste must be used only for inert waste;
5. Criteria for the acceptance of waste at each landfill class must be adopted by the Commission in accordance with the general principles of Annex II.

The following wastes **may not be accepted** in a landfill:

- Liquid waste;
- Flammable waste;
- Explosive or oxidising waste;
- Hospital and other clinical waste which is infectious;

206 www.eur-lex.europa.eu/legal-content/FR/TXT/?uri=CELEX%3A31999L0031.

- Used tyres, with certain exceptions;
- Any other type of waste, which does not meet the acceptance criteria.

3.3. The cost of the non-reusable waste[207]

It is estimated that across the EU, only 40% of our waste is recycled or reused with the rest landfilled or burned. In some other countries it can vary. Every year around 20 billion tons of waste are spread into the oceans and the forecast is that before 2048 all eatable fishes will have disappeared.[208]

It is difficult to estimate but the waste generated in the world is between 3.400 à 4.000 billion tons per year, so from 80 to 126 tons of waste generated every second! Every day, human activity generates more than 10 billions kg of waste. The fuzziness about the number of hazardous waste is very important. Between 2008 and 2020, it is estimated that waste will increase by 40% in the world.[209]

For a company or a farm there are several ways to calculate the cost:[210]

	Production costs	Management costs
External costs	Purchase of raw material, energy, packaging becoming waste	Invoicing of third parties (transport, hiring of bins, treatment costs, taxes)
Internal costs	Working hours necessary to reuse/recycle	Sorting, internal grading, storage, administration…

Calculating the cost of non-reusable waste can be done in effective (monetary) or in non-financial terms. These are evaluated on:[211]

- Recycled collection, sorting and processing costs and associated environmental impacts;
- Organic waste collection and processing costs and associated environmental impacts;
- Processing costs and associated environmental impacts;
- Environmental impacts with landfilling of residuals;

207 www.ademe.fr/entreprises-monde-agricole/reduire-impacts/reduire-cout-dechets/dossier/combien-coutent-dechets/couts-gestion.

208 www.donnees-environnement.com/chiffres-dechets.php#monde.

209 www.planetoscope.com/dechets/363-production-de-dechets-dans-le-monde.html

210 www.ademe.fr/entreprises-monde-agricole/reduire-impacts/reduire-cout-dechets/dossier/combien-coutent-dechets/quest-cout-complet-dechets.

211 www.environment.gov.au/system/files/resources/2e935b70-a32c-48ca-a0ee-2aa1a19286f5/files/landfill-cost.pdf.

- Environmental risks from air pollution;
- Heightened environmental risks Amenity impacts;
- Landfill;
- Incineration Illegal disposal;
- Land consumption;
- Environmental risks from gas emissions and leachate;
- Long-term post-closure management.

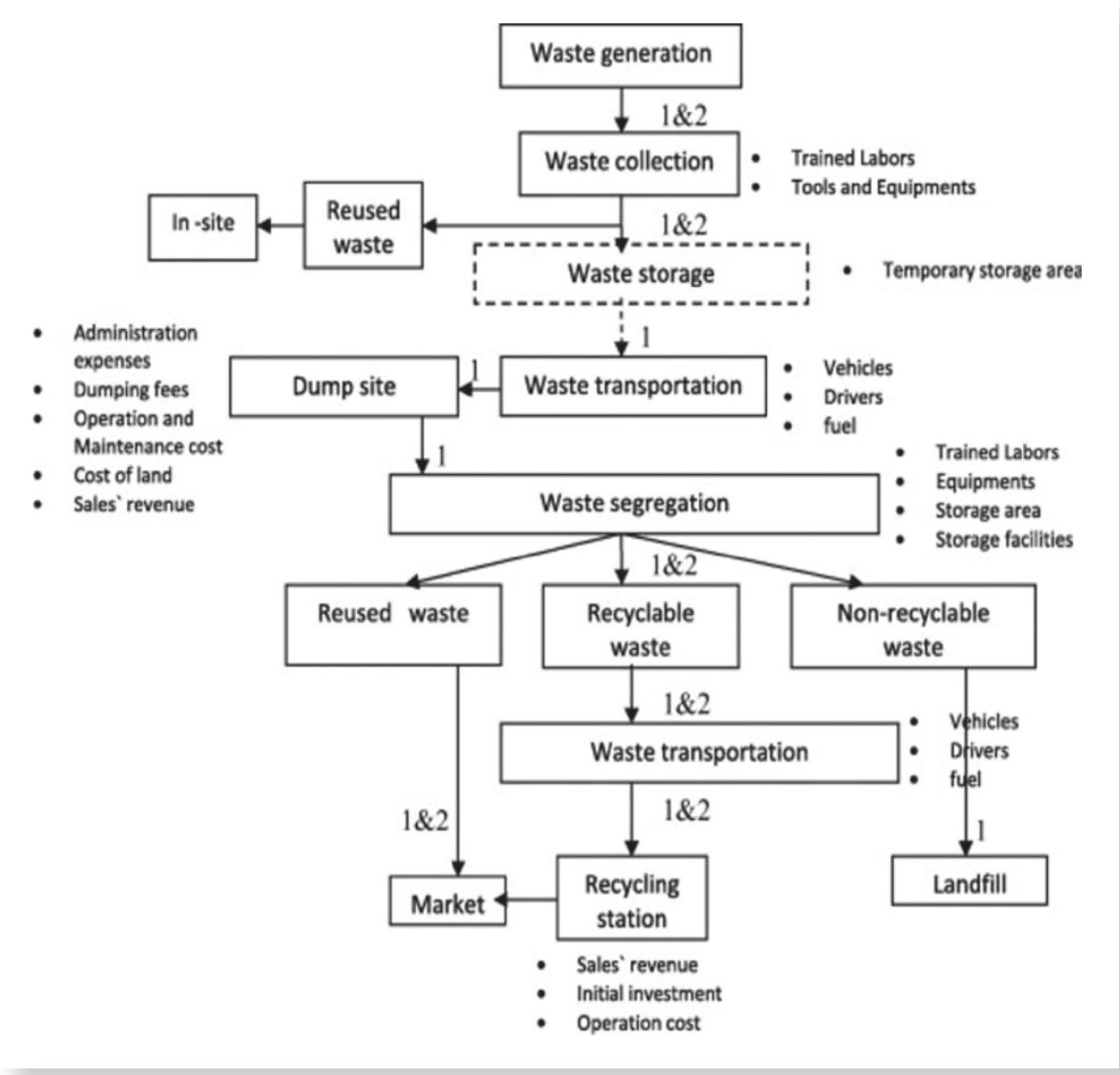
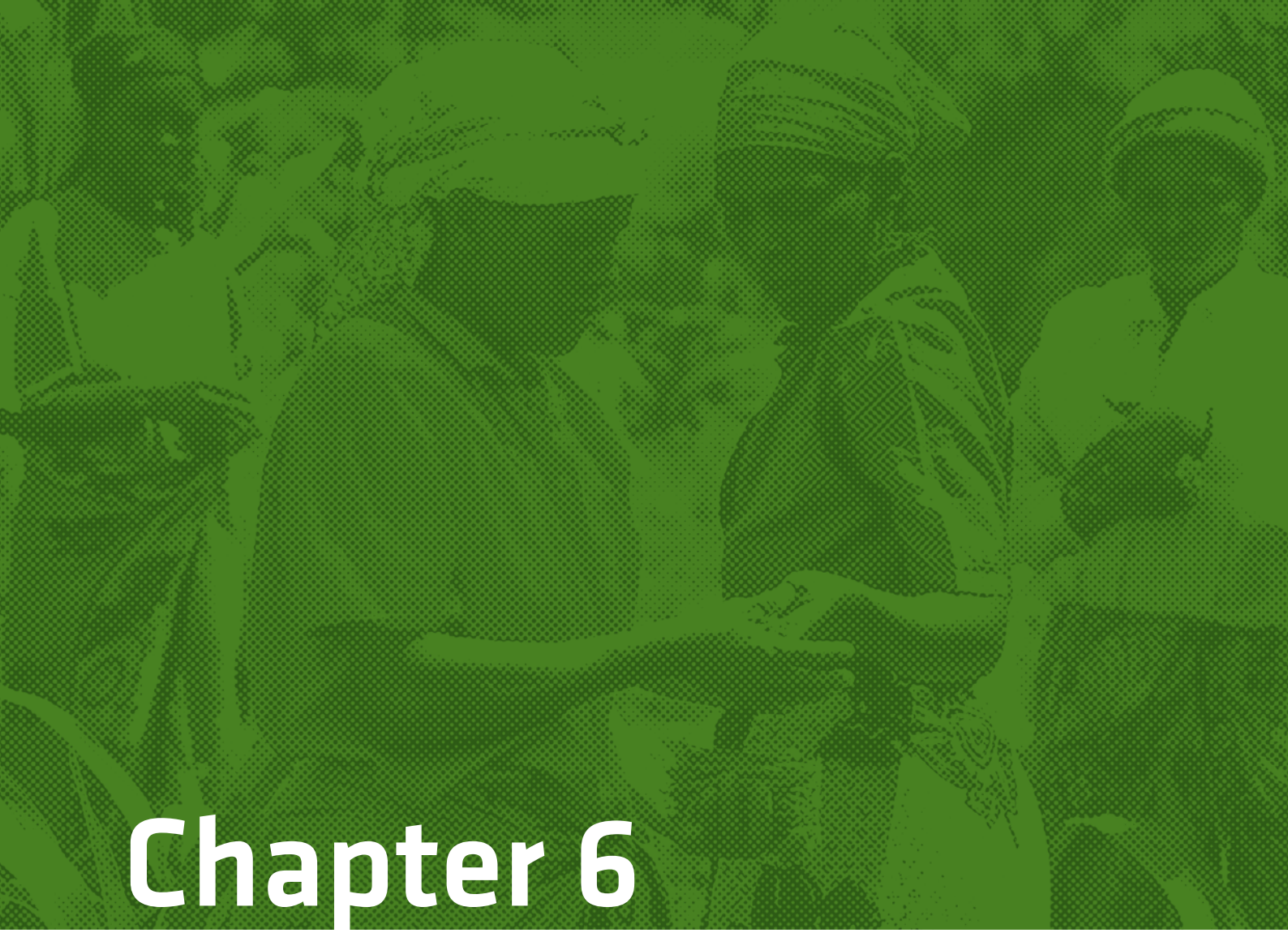


Figure 41: Process and where to add cost or revenues of waste[212]

212 http://ars.els-cdn.com/content/image/1-s2.0-S1687404814000078-gr3.jpg.



Chapter 6

Case Study

PART 1 – A CASE STUDY: WHY, HOW?

Why a case study?

Working from the description of a theoretical case will never replace your professional experience, developed on the ground and in contact with the reality of producers. However, by working through an example taken from situations already encountered, you will develop the methodological principles for analysing a situation, determining the nature and origin of certain problems that may be encountered by them, and create effective and realistic solutions that are compatible with sustainability objectives.

At the end of this case study, the learner will be able to:

- Analyze a wide range of waste management issues
- Propose actions to be carried out to assess the situation
- Determine all the causes and contributors to farm waste on the basis of the theoretical knowledge acquired
- Propose a set of solutions that are appropriate to the business context
- Develop a coherent action plan, using the proposed solutions to deal with all of the identified farm waste problems

Here is an exercise to train you!

A case study should not be used to suggest a 'ready-made recipe' whose ingredients are always the same solutions to recommend to producers. On the contrary, it should enable you **to understand the complexity of the situations that may exist and which require a case-by-case approach**, with appropriate solutions adapted to each situation and to the resources available locally. **The producer must be helped to understand the 'why' of their problems and to determine for themselves 'how' lasting improvements are possible** by making the cost-benefit balance of each theoretically possible solution.

How can you use this case study to review the various aspects of sustainable soil fertility management and apply what you have learned to a case that might be encountered in practice?

This case study chapter consists of **four parts**:

1) Situational setting: By reading a text, the aim will be to identify the information useful for understanding a situation that a horticultural enterprise might encounter (in this case, with regard to soil fertility). In order to refine the diagnosis, it may be necessary to propose to carry out measurements or analyses.

2) Analysis of the situation: In order to identify the causes and propose possible solutions to the company, it will be necessary to analyse the data and make the link between the practices described and the problems encountered (nature, origin, interaction between the observations) and measure the existing gap with the company's objectives.

3) Creating an action plan: Identification of an inventory of solutions that should be appropriate to address each identified problem separately; then ranking of solutions according to how (i) effective; (ii) profitable; (iii) accessible; (iv) sustainable they are.

4) A proposal for an action plan for the company: This will involve establishing an implementation strategy integrating the selected solutions, in order to improve the situation in a sustainable way: maintain or improve soil fertility.

To really benefit from this case study, **you should follow the instructions and carry out each step as a personal exercise**, helping you with the theoretical elements contained in the manual, but also by consulting the Web sites and useful references mentioned in this manual.

At each step you will have instructions, then a solution.

Tip before you begin: Printing the pages in this chapter will make your work easier.

PART 2: THE CASE STUDY OF GARDENFRESH LTD.

2.1. Instructions

***Carefully read this scenario**, describing the difficulties faced by GardenFresh Ltd, a horticultural company selling produce to the local market and exporting to the EU.*[213]

***Identify the important elements** that will help you to understand the nature of the problems of this company. If necessary, print this page to read it again several times.*

GardenFresh Ltd. is a medium-sized fresh produce company that has been managed by three generations of the Joseph family. Currently led by Aimee Joseph, the company started as a market garden business and has grown to produce fresh fruits and vegetables on 20 hectares of land close to a coastal tourist hotspot. The site also has 15 cattle on the farm and 7 goats, which produce milk for the local family and workers. Most of the cattle graze in a small area in the outside fields and the goats are kept in corralled enclosure. At the moment the site collects some manure from the cattle and the goats, but the manure produced is insufficient and of very low quality. This results in a low quality compost. There is not enough land for the cattle to graze and animal feed is an additional expense, so Aimee does not want to expand the number of cattle. Most of the manure is left outside over several weeks, only some is collected when the animals are put back into the shed. Aimee has no idea as to how much manure is being collected from the animals. As a result, GardenFresh is 95% dependent on chemical fertilisers as a form of input. These have become almost 40% more expensive in the last 5 years and represent a significant cost for the farm.

213 Disclaimer: this is a fictional case, and any resemblance to the situations described, the proper names or the denomination of the company would be purely fortuitous.

GardenFresh Ltd. sells fresh vegetables and fruits (mainly tomatoes, peppers, cabbage and pineapple) to wholesalers based in a nearby city as well as to the local market. Produce that is grown for the local or wholesale market is trimmed in the field and bulk-packed on-site in the GardenFresh packing yard.

In addition, a small volume of produce (green beans, tenderstem broccoli, tomatoes and pineapple) is destined for export to Europe. GardenFresh Ltd. works closely with a local packhouse, where their export produce is carefully graded and re-packed ready for shipping. However, the European company that purchases GardenFresh's high-end produce has been acquired by a new retail business with very stringent rules on produce appearance. As a result, around 50% of their shipments have been rejected at the dock recently, meaning a sharp fall in GardenFresh revenues; Aimee has been unable to find an alternative market for most of her shipments which has meant that they have gone to waste. She feels that the basis of the rejections is not always clear or fair, and the packhouse, which grades and packs the produce, have so far been unable to provide any further advice regarding this problem.

Aimee employs a small team of administrative staff, two permanent farm staff and a variable number of seasonal farm workers.

GardenFresh has a good reputation locally and often shares transport logistics with other local farmers, meaning that they are in regular communication. However, locals from the neighbouring village have been complaining about waste polluting their watercourses and have raised this at village meetings; it is not clear how much GardenFresh is to blame and how much has come from other local farmers. Aimee is keen to resolve this issue particularly as many of her seasonal workers come from this village and she is keen to uphold her good company reputation. There is a stream passing through the GardenFresh land and items such as plastic bottles, pieces of irrigation piping, and vegetable residues, have all been seen washed up at the stream edge.

In addition, Aimee decided to invest in some new, higher-yielding pineapple and tomato varieties this year. However, this coincided with good weather patterns and therefore a bumper harvest year locally, meaning that the glut of produce on the local market has driven prices down and also led to large volumes of un-sold produce spoiling. The spoiled produce has often been left in piles at the marketplace, or around the GardenFresh yard, attracting rats and other pests. It is the responsibility of the farm manager to make sure that the farm premises are kept in a clean and tidy order, but he complains that the seasonal workers are not following his advice despite regular verbal reminders about what to do with waste produce.

It is important that the farm manager tackles this problem now as new national waste regulations are being introduced this year. These will mean that GardenFresh needs to report on their hazardous waste management and show the actions they are putting in place to ensure zero contamination and correct disposal. Aimee's administration team has a list of chemicals purchased, such as fertilisers and pesticides, but there is currently no official record detailing how or where product packaging, any un-

used product, and spent application equipment, is disposed of. The new government regulations mean that GardenFresh must dispose of all hazardous waste in a central facility located 70km away; this will be a significant cost to the business.

In addition, Aimee has recently heard that the local tourism bureau is working hard to 'green' the image of its hotels and related businesses. She is also aware that there is very little local supply of fruits and vegetables to hotels as they tend to procure from overseas in order to ensure a year-round supply and cater to overseas taste pallets. Aimee would like to explore the opportunity to supply local hotels with her produce as she sees many opportunities to implement waste reduction initiatives this way, but her fruits and vegetables are seasonal and therefore not in supply year-round.

The GardenFresh family business has been growing slowly and steadily, but as you may see, they are now faced with some new challenges, as well as some opportunities.

2.2. Analysis

***Step 1:** List the problems and suggest steps to further understand the situation*

It is clear that GardenFresh Ltd. is facing a multitude of challenges related to farm waste management. If they are not resolved soon, GardenFresh may be put out of business! Aimee is keen to resolve these issues and has enlisted help from you, a waste management consultant.

Now moving on to the problems that have been raised, list each of the challenges in the tables below, with possible causal reasons for each challenge. Then suggest next steps (e.g. people to interview, information to collect) to further understand the scope and detail of each problem. Use the reference letter (A – E) of each challenge as listed in the problem description above.

You will need to add extra rows to the table in order to address each of the challenges.

Table 1: Challenge A – High cost of chemical fertilisers and low quality manure & compost

Ref.	Challenge	Explanation	Possible reasons
A.1			
A.2			

Table 2: Challenge B – New legislation on hazardous waste

Ref.	Challenge	Explanation	Possible reasons
B.1			
B.2			

Table 3: Challenge C – High rate of rejected produce

Ref.	Challenge	Explanation	Possible reasons
C.1			
C.2			

Table 4: Challenge D – Large volume of unsold produce spoiling

Ref.	Challenge	Explanation	Possible reasons
D.1			
D.2			

Table 5: Challenge E – Pollution of water courses

Ref.	Challenge	Explanation	Possible reasons
E.1			
E.2			

Table 6: Challenge F – Local market opportunities

Ref.	Challenge	Explanation	Possible reasons
F.1			
F.2			

Did you complete your part of the exercise? Well done! Now compare your table to the one suggested below, identify the differences and try to see why your outcome differs from the suggested one. Indeed, you might have had new and/or better ideas! In a few lines, write your analysis and your personal perception: this will help you at the end of the exercise to retrace the logic of your approach.

Table I: Challenge A – High cost of chemical fertilisers and low quality manure & compost

At the moment Aimee and her team collect some manure from the cattle and the goats, but this is insufficient and of poor quality. This is resulting in very poor quality compost. Most of the manure is left outside for weeks on end, only some is collected when the animals are put back into the shed.

Aimee has no idea as to how much manure is being collected from the animals. As a result, GardenFresh is 95% dependent on chemical fertilisers as a form of input. These have become almost 40% more expensive in the last 5 years and represent a significant cost for the farm.

Ref.	Challenge	Explanation	Possible reasons
A.1	High cost of chemical fertilisers	• High dependency on chemical fertilisers	• Lack of training on organic waste management
A.2	Low quality manure	• Poor manure management • Poor manure storage • Poor quality feed	• Insufficient land for cattle to graze. • Insufficient feed to supplement the diet of dary cows. • Leaching and volatilisation of nutrients because manure is left in the open air.
A.3	Insufficient manure for composting	• Manure is left outside • Poor manure collection • There is no current collection of urine.	• Animals are kept in a shed with concrete floors and urine is drained into an outside area. • No collection of manure of cattle in outside areas

Table 2: Challenge B - Meeting national hazardous waste regulations

New national waste regulations mean that GardenFresh need to report on their hazardous waste management and show the actions they are putting in place to ensure zero contamination and correct disposal. Aimee's administration team have a list of chemicals purchased, such as fertilisers and pesticides, but there is currently no official record detailing how or where product packaging, any un-used product, and spent application equipment, is disposed of. The new government regulations mean that GardenFresh must dispose of all hazardous waste in a central facility located 70 km away; this will be a significant cost to the business.

Ref.	Challenge	Explanation	Possible reasons
B.1	GardenFresh have no record of disposal methods or volumes of hazardous waste.	Traditionally, farm management and workers on site have dealt with hazardous waste on an ad-hoc basis, without recording how much waste is generated or where it is disposed of.	There is currently no hazardous waste management plan in place. Staff are not trained in correct hazardous waste management.
B.2	The new regulations stipulate that all hazardous waste should be disposed of at a central facility 70km away.	This transport distance will be financially costly to GardenFresh.	Although hazardous waste is not produced in high volumes, it is produced regularly throughout the year, meaning that regular visits to the central disposal facility will be necessary. Garden Fresh have not addressed hazardous waste levels and therefore have not explored whether they can reduce waste levels.

Table 3: Challenge C - High rate of rejected produce

The European company that purchases GardenFresh's high-end produce has been acquired by a new retail business with very stringent rules on produce appearance. As a result, around 50% of their shipments have been rejected at the dock recently, meaning a sharp fall in GardenFresh revenues; Aimee has been unable to find an alternative market for most of her shipments which has meant that they have gone to waste. She feels that the basis of the rejections is not always clear or fair, and the packhouse, which grades and packs the produce, have so far been unable to provide any further advice regarding this problem.

Ref.	Challenge	Explanation	Possible reasons
C.1	Around 50% of GardenFresh export shipments have been rejected at the dock recently, meaning a sharp fall in GardenFresh revenues.	Garden Fresh produce is not meeting the export customer's requirements. GardenFresh have only one European export customer and are therefore reliant on this customer for all of their export market.	The export customer may have changed its product quality specifications and/or the GardenFresh products are not being correctly graded at the central packhouse. GardenFresh have not explored opportunities with other export customers.
C.2	Most of the rejected produce has ended up going to waste.	Aimee has not found an opportunity to re-sell or redistribute the rejected produce.	Some of the products destined for export are not suited to the local market. It is costly to collect from the packhouse and re-distribute to local markets. Their short shelf life and the high cost of refrigerated transport limits the possibilities for re-organising distribution logistics.

Table 4: Challenge D – Large volume of un-sold produce spoiling

Aimee decided to invest in some new, higher-yielding pineapple and tomato varieties this year. However, this coincided with good weather patterns and therefore a bumper harvest year locally, meaning that the glut of produce on the local market has driven prices down and also led to large volumes of un-sold produce spoiling. The spoiled produce has often been left in piles at the marketplace, or around the GardenFresh yard, attracting rats and other pests. It is the responsibility of the farm manager to make sure that the farm premises are kept in a clean and tidy order, but he complains that the seasonal workers are not following his advice despite regular verbal reminders about what to do with waste produce.

Ref.	Challenge	Explanation	Possible reasons
D.1	Much produce has ended up spoiling as the high yields left a large surplus of unsold produce.	GardenFresh produced more than they were immediately able to sell and did not have any other solutions for the surplus produce.	There was no alternative market available for the surplus fresh produce. GardenFresh has not done any previous market research. GardenFresh have never looked into other sales channels such as dried, juiced or canned produce, which prolongs shelf life and offers new market opportunities. There is currently no longer-term storage solution for the produce; if produce is harvested when ripe, it must be sold straight away.

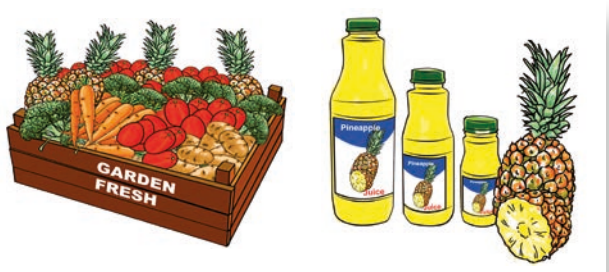
D.2	The spoiled produce was left in piles at the marketplace or around the GardenFresh yard, attracting pests such as rats.	Waste is not being correctly handled by farm staff. Seasonal workers are not following the advice of the farm manager, when asked to clear the GardenFresh yard and deal with waste.	There is no waste management protocol and training given to farm staff or seasonal workers Seasonal workers are not aware of the importance of maintaining yard hygiene. Seasonal workers do not see it as their role to clear away spoiled produce, as they have been employed for other roles and duties Seasonal workers do not know what to do with the large volume of spoiled produce.

Table 5: Challenge E – Pollution of watercourses

Locals from the neighbouring village have been complaining about waste items polluting their watercourses and have raised this at village meetings; it is not clear how much the GardenFresh farm and packhouse are to blame and how much has come from other local farmers. However Aimee is keen to resolve this issue particularly as many of her seasonal workers come from this village and she is keen to uphold her good company reputation. There is a stream passing through the GardenFresh land and items such as plastic packaging, pieces of irrigation piping, and vegetable residues, have all been seen washed up at the stream edge.

Ref.	Challenge	Explanation	Possible reasons
E.1	Locals from the neighbouring village have complained to GardenFresh about farm waste polluting their watercourses.	Waste from the farm or packhouse may be washed into the stream during heavy rains or blown in by the wind. Wastewater from the packhouse is entering the stream.	Waste is not being properly disposed of by farm and packhouse staff or contractors. There are no collection points for non-organic and organic waste in the fields. Staff and contractors may be unaware of proper waste disposal protocol. There are no vegetation buffers such as bushes or reeds, along the banks of the stream, to protect it from rainwater or wind spreading litter that accidentally ends up in the vicinity. There is no wastewater treatment facility on-site.
E.2	Aimee is keen to resolve this issue to uphold the good reputation of GardenFresh	Aimee employs many locals as farm staff or seasonal workers. In addition, waste that is from other farms is entering the watercourse.	Aimee wants her business to be seen as a local leader for good waste management. Other local farms do not have a good waste management protocol.

Table 6: Challenge F – Local market opportunities



Aimee has heard that the local tourism bureau is working hard to 'green' the image of its hotels and related businesses. She is also aware that there is very little local supply of fruits and vegetables to hotels as they tend to procure from overseas in order to ensure a year-round supply and cater to overseas taste pallets. Aimee would like to explore the opportunity to supply local hotels with her produce as she sees many opportunities to implement waste reduction initiatives this way, but her fruits and vegetables are seasonal and therefore not in supply year-round.

Ref.	Challenge	Explanation	Possible reason
F.1	There is currently very little local supply of fruits and vegetables to hotels	Hotels require a reliable year-round supply and therefore rely on overseas suppliers. Hotels wish to cater for overseas pallets. Farms such as GardenFresh have not explored this opportunity with hotels before.	Individually, local farmers are unable to supply the volumes or range of produce required by hotels. They think tourist would not appreciate local produces Aimee is unsure which products (fruits, vegetables, salads, fresh, dried, juiced) are of interest to the local hotels.
F.2	Aimee does not know which products would be interesting	Aimee has not enough contact with the hotels and then is unsure what products the hotels are interested in. Aimee does not know whether they are interested in the GardenFresh current range of fresh produce and also in value-added products such as dried or juiced fruits.	There may be potential for GardenFresh to reduce waste whilst simultaneously adding value if they can secure a buyer in the high-end tourism market, particularly for value-added produce such as dried fruits which have a prolonged shelf life.

***Step 2:** Suggest solutions to each of the challenges identified in Step 1*

To help Aimee, we must propose **appropriate solutions to deal with each Challenge** identified during 2.3. Work in **two steps**:

A. Briefly list the possible solutions to each problem in the tables, below.

B. Then evaluate how practical and sustainable each of these solutions are: in Table form, list each solution and **rate them from 1 – 4** (with 1 being the lowest score and 4 being the highest) for each of **the following four scoring categories**:

- Effective;
- Cost-effective;
- Accessible;
- Long lasting.

A) Listing solutions for each challenge

Briefly list the possible solutions to each problem identified in the tables created at Step 1, as shown in the example below.

Table 1: Challenge and solutions A – High cost of chemical fertilisers and low quality manure & compost

Ref.	Challenge	Solutions	Next steps
A.1	High cost of chemical fertilisers	Reduce the dependency on chemical fertilisers	Identify sources of organic waste that can be used as fertilisers

Table 2: Challenge and solutions B – New legislation on hazardous waste

Ref.	Challenge	Solutions	Next steps
B.1			
B.2			

Table 3: Challenge and solutions C – High rate of rejected produce

Ref.	Challenge	Solutions	Next steps
C.1			
C.2			

Table 4: Challenge and solutions D – Large volume of unsold produce spoiling

Ref.	Challenge	Solutions	Next steps
D.1			
D.2			

Table 5: Challenge and solutions E – Pollution of watercourses

Ref.	Challenge	Solutions	Next steps
E.1			
E.2			

Table 6: Challenge and solutions F – Local market opportunities

Ref.	Challenge	Solutions	Next steps
F.1			
F.2			

You will need to add more lines to each table.

Did you complete your part of the exercise? Well done! Now compare your table to the one suggested below, identify the differences and try to see why your outcome differs from the suggested one. Indeed, you might have had new and/or better ideas! In a few lines, write your analysis and your personal perception: this will help you at the end of the exercise to retrace the logic of your approach.

Table I: Challenge A – High cost of chemical fertilisers and low quality manure and compost

Ref.	Challenge	Ref.	Solutions	Next steps
A.1	High cost of chemical fertilisers	S.1	Reduce the dependency on chemical fertilisers	Training for farm staff on fertilizers management and organic waste management. Identify sources of organic waste that can be used as fertilisers

A.2	Low quality manure	S.2	Create a manure Management Plan: • consult an agronomist to understand what the input requirements for the crops. • Include targets for collection. • measure quality of the manure • Review Current Storage system for manure.	Measure how much manure is being produced at the end of each day in the sheds and in the fields. Using the 5 M model. Identify a small team of people to collect manure from the fields and the corralled areas at the end of each day.
		S.3	Use surplus and residue crop to supplement feed for the animals	Consult a veterinary surgeon to identify the types of crop residue that can be used as part of the animal feed.
A.3	Insufficient manure for composting	S.4	Collect manure daily from the field and corralled areas.	Build a shed (or extend existing animal shed) to store animal manure.
		S.5	Create urine drains from the cow shed.	Review current systems for collecting urine the sheds and in particular bedding.
		S.6	Review current composting management system and Identify the most appropriate composting method: i) Windrow method ii) Aerated Pile iii) Box composting iv) Pit composting v) Vermi-composting Identify one person to be in charge of the composting plan.	Ensure that all indoor areas are covered with straw Make sure the straw is kept and stored for making compost. Train the farm manager and a small team of people on windrow composting techniques.

Table 2: Challenge and Solutions B – New legislation on hazardous waste

Ref.	Challenge	Ref.	Solutions	Next steps
B.1	GardenFresh have no record of disposal methods or volumes of hazardous waste.	S.7	Create a hazardous waste management plan. (Example at Part 4)	Appoint a member of staff to work with Aimee and take on the task of developing the plan. Create a new record-keeping system, detailing all hazardous waste streams occurring at GardenFresh including volumes, dates and end-of-life fate. Identify opportunities to reduce hazardous waste across the business.
B.2	The new regulations stipulate that all hazardous waste should be disposed of at a central facility 70km away.	S.8	Form a farmers' cooperative with other local farm businesses: this could offer opportunities to share transport costs.	Arrange a meeting with other local farmers to identify opportunities to work together on shared logistics.

Table 3: Challenges and Solutions C – High rate of rejected produce

Ref.	Challenge	Ref.	Solutions	Next steps
C.1	Around 50% of GardenFresh export shipments have been rejected at the dock recently, meaning a sharp fall in GardenFresh revenues.	S.9	Review "Marketing standard for tomatoes" Commission implementing regulation (EU) No 543/2011 to ensure quality parameters are being implemented by both the packhouse and the retailer.	(i) Visit the packhouse in person and meet with the relevant personnel (Quality Control, European customer Account Manager). It can then be determined why such a high rate of rejections are occurring. (ii) Organise a conference call with the buyers to understand what is driving the rejection of produce at their end.
		S.10	Identify other export customers for GardenFresh to increase their sales channels.	Identify and set up pre-purchase agreement contract with another export customer in order to diversify the export customer base and shift away from difficult customer over the long-term.
C.2	Most of the rejected produce has ended up going to waste.	S.11	Identify alternative uses for the rejected produce: (i) Sell to a nearby processing factory (ii) Return to the farm for composting or energy recovery +animal feed	Identify whether there are processing factories close to the export packhouse, such as a tomato paste producer or pineapple canner/juicer. Create a composting site at the farm to make use of waste produce and contribute to reduced dependency on chemical fertilisers.

Ref.	Challenge	Ref.	Solutions	Next steps
		S.12	Hold a meeting with the farmers cooperative to arrange shared return transport logistics.	Arrange a meeting with a group of local farmers to find out more and discuss solutions collectively, in order to share the cost of returning rejected produce to the farm or to an alternative market.

Table 4: Challenges and Solutions D – Large volume of un-sold produce spoiling

Ref.	Challenge	Ref.	Solutions	Next steps
D.1	Much produce has ended up spoiling as the high yields left a large surplus of unsold produce.	S.13	Identify new customer bases such as local tourism businesses.	Research options for alternative sales channels for their fresh produce. Are local tourism businesses interested in their produce? What is the size of the local tourism market? Organise meetings with hotel and restaurant procurement to determine whether they would be interested in purchasing GardenFresh produce.
		S.14	Prolong the shelf life of some products by processing into dried or juiced or other forms.	Identify whether there is a local market for these products and what could be the environmental impact of the technologies. How can they make it easy for customers to recycle packaging? What type of packaging is most suitable for conserving and marketing this produce that: • is cost effective • has minimal impact in terms of waste • can be recycled

Ref.	Challenge	Ref.	Solutions	Next steps
D.2	The spoiled produce was left in piles at the marketplace or around the GardenFresh yard, attracting pests such as rats.	S.15	Identify a member of staff to work with Aimee to develop an organic waste management protocol as part of the overall waste management plan.	i) Identify the types, volumes and locations of spoiling produce that is being produced. ii) Explore options for recycling waste: are there any opportunities to generate revenue or energy from waste streams: Composting Animal feed Energy recovery such as Biogas
		S.16	Create and implement a waste management training programme for all staff including information points around the farm to regularly remind all workers of the correct protocol.	i) Interview a sample of seasonal workers to understand the current situation and help to inform an action plan. ii) Develop an organic waste management protocol as part of the overall waste management plan. iii) Develop visual guidance on yard hygiene, including posters and labelled bins. Make sure these are well presented and understood by all. iv) Ensure that all workers across the site understand their responsibilities for waste management and how to manage waste streams at each point of production.

Table 5: Challenges and solutions E – Pollution of watercourses

Ref.	Challenge	Ref.	Solutions	Next steps
E.1	Locals from the neighbouring village have complained to GardenFresh about farm waste polluting their watercourses.	S.17	Develop a waste management plan and training protocol for the entire Garden Fresh business. This should include the on-site packhouse as well as the farm.	Visit the village and see the problem; identify what types of waste are being washed along the stream and how they may end up there. if the origin of some wastes is not the farm, communicate with other possible polluters to find common solutions. Ensure that waste can be disposed of properly: • Set up collection points for waste in the fields and throughout the site for non-organic and organic waste. • Establish a time for a waste pick up truck to do the rounds at the end of the day. • Set up an area to store and collect organic and non-organic waste centrally on site. • Measure the amount of waste being generated daily. • Communicate waste plan and procedure to new workers and subcontractors. • Develop visual guidance materials, such as posters and labelled bins or containers, in prominent positions around the farm.

Ref.	Challenge	Ref.	Solutions	Next steps
		S.18	Establish vegetation buffers along the banks of the stream and any other watercourses bordering the farm (e.g. reservoirs, fish ponds etc.).	Identify the areas on site that are at risk of run off water entering the stream. Establish buffer zones to ensure waste water and run off does not go into the water channels at Garden Fresh. Where gaps in vegetation exist along the riverbank, begin to re-plant with native riparian plants such as reeds. Consider: • Developing cover crops to reduce erosion, absorb excess fertilizer and reduce nutrient leaching. • Developing buffers, such as grasses, trees and shrubs planted along the edges of farm fields and along rivers and streams to reduce the amount of pollutants flowing into local waterways. • Using streamside fences to exclude livestock from local waterways and reducing the amount of nutrients and pathogens entering the water.
		S.19	Build a wastewater treatment system, where all used water (e.g. for washing equipment, washing produce etc.) can flow and be cleaned. (See Part 4)	Identify a good location for collecting wastewater. Identify the most appropriate type of wastewater treatment facility that can be built on-site to clean and recycle water, ready to be used again on the farm for irrigation.
E.2	Aimee is keen to resolve this issue to uphold the good reputation of GardenFresh	S.20	Hold or sponsor some community waste awareness training events in the village, to increase local understanding of good waste management practice and why it is important. Communicate.	Talk to community leaders and the local schools to arrange training sessions. Produce information posters to be placed in and around the village. Training materials should be developed in parallel

Table 6: Challenges and solutions F – Local market opportunities

Ref.	Challenge	Ref.	Solutions	Next steps
F.1	There is currently very little local supply of fruits and vegetables to hotels	S.21	Team up with other farmers – by forming a cooperative – to have the production capacity and variety to supply hotels year-round.	Organise a meeting with local farmers to begin discussions on forming a sales cooperative.
		S.22	Identify the range of produce of interest to tourism businesses.	Approach several hotel and restaurant operators to determine the range of fresh produce they procure and whether they are interested in sourcing from local, high-quality producers. Set up sales channel with 5 local high-end eco-tourism facilities. Agree purchase contracts over a trial period.
F.2	Aimee is unsure what products the hotels are interested in.	S.23	Identify a small range of value-added or out-graded products that GardenFresh can offer to tourism businesses: dried fruits and out-graded fruit for juicing.	Identify simple options for creating value-added products: do any of the farmers in the local cooperative have processing facilities such as solar dryers? Would these facilities be appropriate for the types and varieties of produce grown at GardenFresh? Hold meetings with tourism businesses to pitch the range of products that GardenFresh would like to sell.

B) Rating solutions for each challenge

Now it is time to **evaluate the suitability of each solution**. Give **each solution a score from 1 - 4** (with 1 being the lowest score and 4 being the highest) according to how effective, cost-effective, accessible (easy to implement) and long-lasting they will be as stand-alone solutions.

Then add up the total score per solution.

Solutions can then be implemented in a phased process, with higher scores given focus earlier on, and those with lower scores implemented at a later stage. It might be that certain solutions should be implemented together in order to be effective; if this is the case, note the partnered solution(s) in the final column of the table.

Table 7: Scoring each solution. 1 = weak. 2 = average. 3 = good. 4 = excellent

Ref.	Solution (1 = weak. 2 = average. 3 = good. 4 = excellent.)	Effective	Cost-effective	Accessible	Long-lasting	Total score	Partner solution(s)
S.1	Reduce the dependency on chemical fertilisers	4	3	3	4	14	S.2,3,4,5,6
S.2	Create a manure management plan	4	4	4	4	16	S.1,3,4,5,6
S.3	Use surplus and residue crop to supplement feed for the animals	4	4	3	3	14	S.1,2,4,5,6
S.4	Collect manure daily from the field and corralled areas.	4	4	3	4	15	S.1,2,3,5,6
S.5	Create urine drains from the cow shed.	4	2	3	4	13	S.1,2,3,4,6
S.6	Review current composting management system & identify the most appropriate composting method	4	4	4	3	15	S.11,15
S.7	Create a hazardous waste management plan.	4	3	3	4	14	S.16,17
S.8	Form a farmers' cooperative with other local farm businesses.	3	2	2	4	11	S.12,21
S.9	Review "Marketing standard for tomatoes" Commission implementing regulation (EU) No 543/2011 to ensure quality parameters are being implemented by both the packhouse and the retailer	2	4	3	4	13	
S.10	Identify other export customers for GardenFresh to increase their sales channels.	3	2	3	4	12	
S.11	Identify alternative uses for the rejected produce: (i) Sell to a nearby processing factory (ii) Return to the farm for composting or energy recovery	4	2	2	4	12	S.15,23

Ref.	Solution (1 = weak. 2 = average. 3 = good. 4 = excellent.)	Effective	Cost-effective	Accessible	Long-lasting	Total score	Partner solution(s)
S.12	Hold a meeting with the farmers cooperative to arrange shared return transport logistics.	3	3	3	4	13	S.8,12,21
S.13	Identify new customer bases such as local tourism businesses.	3	2	3	3	11	S.21,22,23
S.14	Prolong the shelf life of some products by processing into dried or juiced or other forms.	4	2	2	4	12	S.11,22,23
S.15	Identify a member of staff to work with Aimee to develop an organic waste management protocol as part of the overall waste management plan.	4	3	4	4	15	S.2,16,17
S.16	Create and implement a waste management training programme for all staff including information points around the farm to regularly remind all workers of the correct protocol.	4	3	4	4	15	S.2,7,15,17
S.17	Develop a waste management plan and training protocol for the entire Garden Fresh business. This should include the on-site packhouse as well as the farm.	4	4	4	4	16	All solutions relevant.
S.18	Establish vegetation buffers along the banks of the stream and any other watercourses bordering the farm (e.g. reservoirs, fish ponds etc.).	3	2	3	3	11	S.19
S.19	Build a wastewater treatment system, where all used water (e.g. for washing equipment, washing produce etc.) can flow and be cleaned. (See Part 4)	4	2	2	4	12	S.18
S.20	Hold or sponsor some community waste awareness training events in the village, to increase local understanding of good waste management practice and why it is important.	3	2	4	4	13	S.16,17
S.21	Team up with other farmers – by forming a cooperative – to have the production capacity and variety to supply hotels year-round.	3	3	3	4	13	S.8
S.22	Identify the range of produce of interest to tourism businesses.	3	3	2	3	11	S.13,21,23
S.23	Identify a small range of value-added or out-graded products that GardenFresh can offer to tourism businesses: dried fruits and out-graded fruit for juicing.	3	2	2	3	10	S.13,21,22

PART 3: CREATING AN ACTION PLAN

Now that you have listed your solutions and identified their scores and partner solutions, you can devise an action plan for GardenFresh!

Let's view this as a series of steps, to be implemented over a set period, perhaps over one year. For example:

Step 1 should contain **the most important and high-scoring solutions**, as well as any partner solutions, which make sense to be implemented at the same time.

Step 2, the next most important and **decent-scoring solutions** and partner solutions.

The final steps 3, 4, 5 and so on will contain lower-scoring and/or less urgent solutions.

Once the action plan has been fully-implemented, GardenFresh should be well on their way to becoming an exemplary model of excellent farm waste management.

Based on their scores and partner solutions, the following Steps have been identified for our Action Plan:

Step 1: S.17 (Score 16)
Step 2: S.6, S.7, S.15, S.16 (Scores 14 – 15)
Step 3: S.1, S.2, S.3, S.4, S.5 (Scores 13 – 16)
Step 4: S.S.9, S.10, S.11 (Scores 12 – 13)
Step 5: S.18, S.19, S.20 (Scores 11 – 13)
Step 6: S.8, S.12, S.21 (Scores 11 – 13)
Step 7: S. 13, S.14, S.22, S.23 (Scores 10 – 12)

Next we outline our action plan steps in a flow diagram.

Step 1: Waste management planning

The first step towards waste management is proper planning. A waste reduction action plan (WRAP) will result in lower waste levels across the business. At a time when the costs associated with business inputs and waste handling are increasing, a waste management plan is a good way of exploring cost-saving solutions. Begin by reviewing every element of the GardenFresh business: administration, packhouse, transport, production. Create a flow diagram for each of these elements, listing their processes and inputs. For example, production includes fertilisers, pesticides, irrigation and so on.

S.17 Develop a waste management plan and training protocol for the entire Garden Fresh business. This should include the on-site packhouse as well as the farm.

Step 2: Getting organised to implement the farm waste management plan

Now that the waste management plan has been created for the entire business, it is time to begin implementing the plan. Identify the relevant member(s) of staff for managing each process, develop and disseminate training, and start to organise some larger-scale solutions.

Training is an important step in ensuring that the management plans and protocols are put into place. It is important that all farm staff, whether temporary or permanent, are given adequate training so that they understand how and why waste should be managed.

S.6 Review current composting management system & identify the most appropriate composting method .	S.7Create a hazardous waste management plan.	S.15 Identify a member of staff to work with Aimee to develop an organic waste management protocol as part of the overall waste management plan.	S.16 Create and implement a waste management training programme for all staff including information points around the farm to regularly remind all workers of the correct protocol.

Step 3: Converting Organic Waste from Mixed farming

This step uses resources that are already on the farm, it affects livestock health and could represent a significant cost saving for the site in terms of fertiliser cost. It could also have a significant environmental impact given that a mixed farming approach would reduce the dependency on chemical inputs.

S.1 Reduce the dependency on chemical fertilisers	S.2 Create a manure management Plan	S.3 Use surplus and residue crop to supplement feed for the animals	S.4 Collect manure daily from the field and corralled areas.	S.5 Create urine drains from the cow shed.

Step 4 Solving the export problem

This step addresses the issue of lost revenues from export sales. This is suggested as a three-pronged approach: first reviewing the reasons behind export product rejections, then diversifying the customer portfolio so that no single export customer is relied upon, and finally, identifying alternative uses for the rejected produce that also benefit GardenFresh.

S.9 Review "Marketing standard for tomatoes" Commission implementing regulation (EU) No 543/2011 to ensure quality parameters are being implemented by both the packhouse and the retailer	S.10 Identify other export customers for GardenFresh to increase their sales channels.	S.11 Identify alternative uses for the rejected produce: (i) Sell to a nearby processing factory; (ii) Return to the farm for composting or energy recovery

Step 5: Safeguarding the environment

Waste management affects everybody in and around the community; improper management can lead to public health problems such as disease spread and poisoning of wildlife including species relied upon for food (eg. fish). Protecting local watercourses, including streams, rivers and groundwater, will help to ensure the health and safety of the local environment and the biodiversity and communities dependent on them, as well as ecosystems further afield whose watercourses may be linked. At the same time, locals who may contribute to this source of pollution should also be involved in understanding how to better-manage their waste. This step deals with physical barriers and education to stop waste from escaping into the natural environment.

S.18 Establish vegetation buffers along the banks of the stream and any other watercourses bordering the farm (e.g. reservoirs, fish ponds etc.).	S.19 Build a wastewater treatment system, where all used water (e.g. for washing equipment, washing produce etc.) can flow and be cleaned. (See Part 4)	S.20 Hold or sponsor some community waste awareness training events in the village, to increase local understanding of good waste management practice and why it is important.

Step 6: Working together

Working together with other farm business can bring a multitude of benefits, from shared logistics to greater negotiating power and shared facilities. It can be a costly process to implement when the correct legal structures and processes are followed, but the "strength in numbers" can create long-lasting, positive effects.

S.8 Form a farmers' cooperative with other local farm businesses.	S.12 Hold a meeting with the farmers cooperative to arrange shared return transport logistics.	S.21 Team up with other farmers – by forming a cooperative – to have the production capacity and variety to supply hotels year-round.

Step 7: Marketing and sales GardenFresh need to address the issue of lost revenues from export sales and surplus production. By diversifying the product offerings and also the customer portfolio so that no single export customer is relied upon, the business will build more financial resilience whilst reducing the amount of fresh produce that ends up as waste.			
S.13 Identify new customer bases such as local tourism businesses.	S.14 Prolong the shelf life of some products by processing into dried or juiced or other forms.	S.22 Identify the range of produce of interest to tourism businesses.	S.23 Identify a small range of value-added or out-graded products that GardenFresh can offer to tourism businesses: dried fruits and out-graded fruit for juicing.

PART 4: DEVELOPING SUPPLEMENTARY MATERIALS

You may use this time to develop any further materials that you feel would be important to the implementation of any Solutions.

Now compare notes! We have outlined some extra materials

(I) Identify the different types of waste according to the 5 M's

Before coming up with recommendations as to what to do with the waste, you need to ensure that you have identified and quantified waste streams correctly. Although you may not be able to measure the exact quantities of waste immediately, you should include a column to capture the weight or units of waste being generated on site. Remember what can't be measured can't be managed or improved!

Your first step is to identify the different waste streams by focusing on the management of organic and non-organic waste generated **from 5 key areas**, or 5 M's.

You will need to add extra rows to the tables below to capture any additional waste streams.

1. Mainland (Waste generated on the farm)

Organic waste	Kg	Units	Non organic waste	Kg	Units
Run off liquid from irrigation			Chemical Fertilisers		
Waste liquid used for cleaning produce			Chemical Pesticides		
Animal manure (urine and feces)			Chemical containers		
Vegetation and plant waste such as cuttings, branches, leaves			Plastic sheets and hose pipes		
			Polytunnel plastic		
			Damaged fencing		
			Contruction materials		

2. Manpower (Workforce)

Organic waste	Kg	Units	Non organic waste	Kg	Units
Human waste (urine/ feces)			PPE such as gloves, hats, masks, overalls, aprons,		
Left over food			Plastic		
Liquid waste from cleaning utensils			Glass		
Liquid waste from baths and showers			Metal		
			Paper and Cardboard		

3. Materials (Harvest and Processing)

Organic waste	Kg	Units	Non organic waste	Kg	Units
Excess product			Damaged packaging		
Damaged product			Damaged plastic wraps and containers		
Waste liquid from washing product			Damaged Tins, glass jars and lids		
			Damaged tools		

4. Method (Product design and Storage)

Organic waste	Kg	Units	Non organic waste	Kg	Units
Discarded product which does not meet client specifications (weight, size, appearance)			Excess packaging		
			Damaged Crates and bags		
			Damaged Pallets		
			Fuel used in transportation		

5. Machinery (and Equipment)

Organic waste	Kg	Units	Non organic waste	Kg	Units
			Oils and fuels		
			Spare tyres		
			Broken machine parts		
			Batteries		
			Broken sprayers		

(II) Create a manure management plan

See Chapter 4. to help you develop a manure management plan. Then follow these steps to ensure that you can start your transition to a more self-sufficient manure and composting system:

- Firstly, evaluate your requirements for fertiliser based on your crops, soil tests, manure quality and quantity.
- Secondly, consider where and when to apply manure, making sure to minimise leaching, volatilisation and run off into waterways.
- Thirdly, to maintain nutrients in manure, consider livestock feed, housing, collection and storage of manure.

(III) Use surplus and discarded crop to supplement feed for the animals: Finding the right feed[214]

Monogastric animals such as pigs and poultry are often farmed commercially are predominantly fed on concentrates produced by feed mills using grain. These are foods that humans also consume and strong demand keeps prices high. In most countries, feed accounts for up to 65% of poultry production costs.

214 SPORE: The magazine for agricultural and rural development in ACP countries. N.174, February to March 2015. http://archive.spore.cta.int/en/component/content/article?id=11543:feeding-africa-s-livestock.

Given population growth, new research is being conducted into alternative sources of ingredients including agro-industrial waste products

With cattle the situation is slightly different, whilst some concentrates are fed to dairy and beef cattle, the main source of livestock feed for ruminants, including cattle and goats includes crop residues, forages and fodder shrubs. There are many cover crops can be used for grazing. Common choices for covers include cereal grains, oats, annual ryegrass, peas, vetch, sudangrass, brassicas, and clovers.

Nearly 1,400 livestock feed resources are included in Feedipedia, an open encyclopedia of animal feed resources. The feed resources are categorised in four main categories: forage plants, plant products/by-products, feed of animal origin, and other feeds, which are further divided into sub-categories. The main objective of Feedipedia is to provide extension and development workers, planners, livestock farmers, researchers and policymakers, amongst others, with the latest information to help them identify, characterise and properly use feed resources to sustainably develop the livestock sector. The information is jointly managed by FAO and the French research institutes, AFZ, CIRAD and INRA (www.feedipedia.org).

(IV) Creating a hazardous waste management plan

See Chapter 5 of this Waste Management manual to help you identify all hazardous waste streams occurring on-site. Then follow these steps to ensure that you comply with the new legislation. (Note – these are a hypothetical set of recommendations based on EU legislation; each country should research their own national laws to ensure compliance.)

- Firstly, ask supplier if they will take back any unwanted, unused pesticides that are packaged, labelled and of good quality;

  Pesticide concentrates are likely to be 'hazardous waste' (sometimes known as 'special waste') and may present a significant risk to the environment or to humans. Handling and disposing of this type of waste is tightly controlled and you will need to use a registered carrier (registered with the Environment Agency) and a licensed waste-disposal contractor (you will be able to find one in The Phone Book);

- Store unwanted concentrates and ready-to-use formulation in a **chemical store** to make sure they are secure and that any spills will be contained;

- If you can transport your own unwanted pesticides safely and legally, you can take these to a **licensed treatment or disposal site**, *after checking whether the site will accept your waste.*

- You (or the carrier if you use one) must fill in a *'***consignment note***'* and pay a fee to the Environment Agency if you are moving or disposing of 'hazardous waste'. You (as the waste producer) and the people transporting and receiving

the waste must keep copies of the consignment notes *for at least three years*. Also, you must not move 'hazardous waste' until the appropriate period for notice has passed;

- When you have filled in the necessary consignment notes, you should pass the unwanted concentrates **to a licensed waste-disposal contractor**.

- As the producer of the waste, you must make sure that the person who takes your waste is registered to take it and can transport it safely, and that it will be safely disposed of or recycled;

- You must also fill in a '**waste transfer note**' and provide a written description of the waste (you can write this on the transfer note itself). Both you and the waste-disposal contractor must keep copies of the transfer note and written description for two years. If the waste is 'hazardous' and you have filled in a 'consignment note', you do not also need to fill in a 'waste transfer note'.

(V) Beginning talks with other local farmers about forming a cooperative

There are a multitude of opportunities which may result from forming a local farmers' cooperative, such as group training events on waste management, shared transport logistics including for hazardous waste management, and shared investment into value-adding processing technology (e.g. solar driers) to process out-graded and/or surplus produce.

Members of the cooperative need to be in agreement about the services they will provide, how decisions will be made, and how the business management will be operated.

(VI) Review the "Marketing standard for tomatoes" Commission implementing regulation (EU) No. 543/2011 to ensure quality parameters are being implemented by both the packhouse and the retailer

Anyone who markets fresh fruit or vegetables, salad crops, nuts or cultivated mushrooms must meet the rules on quality and labeling.

Producers should review **EU Marketing Standards for Fresh Horticultural Produce**.[215]

These standards are designed to help promote fair competition throughout the marketing chain. They provide consistent quality, grading and labelling which allows produce to be bought without being seen. This also provides a guarantee of the produce when being bought by telephone or the Internet.

For the grower, the standards are established to make sure that produce is traded fairly, with a consistent and detailed system of quality, grading and labelling. They help to improve the returns to growers for good quality produce, by preventing unfair

215 www.gov.uk/guidance/comply-with-marketing-standards-for-fresh-fruit-and-vegetables.

competition from poor quality produce, or produce falsely claimed to be of a higher quality than it is.

The marketing standards apply to all businesses in the FSC, including importers, packers (who may also be growers), distributors, wholesalers, retailers (who may not necessarily trade from shop premises).

There are 2 main standards:

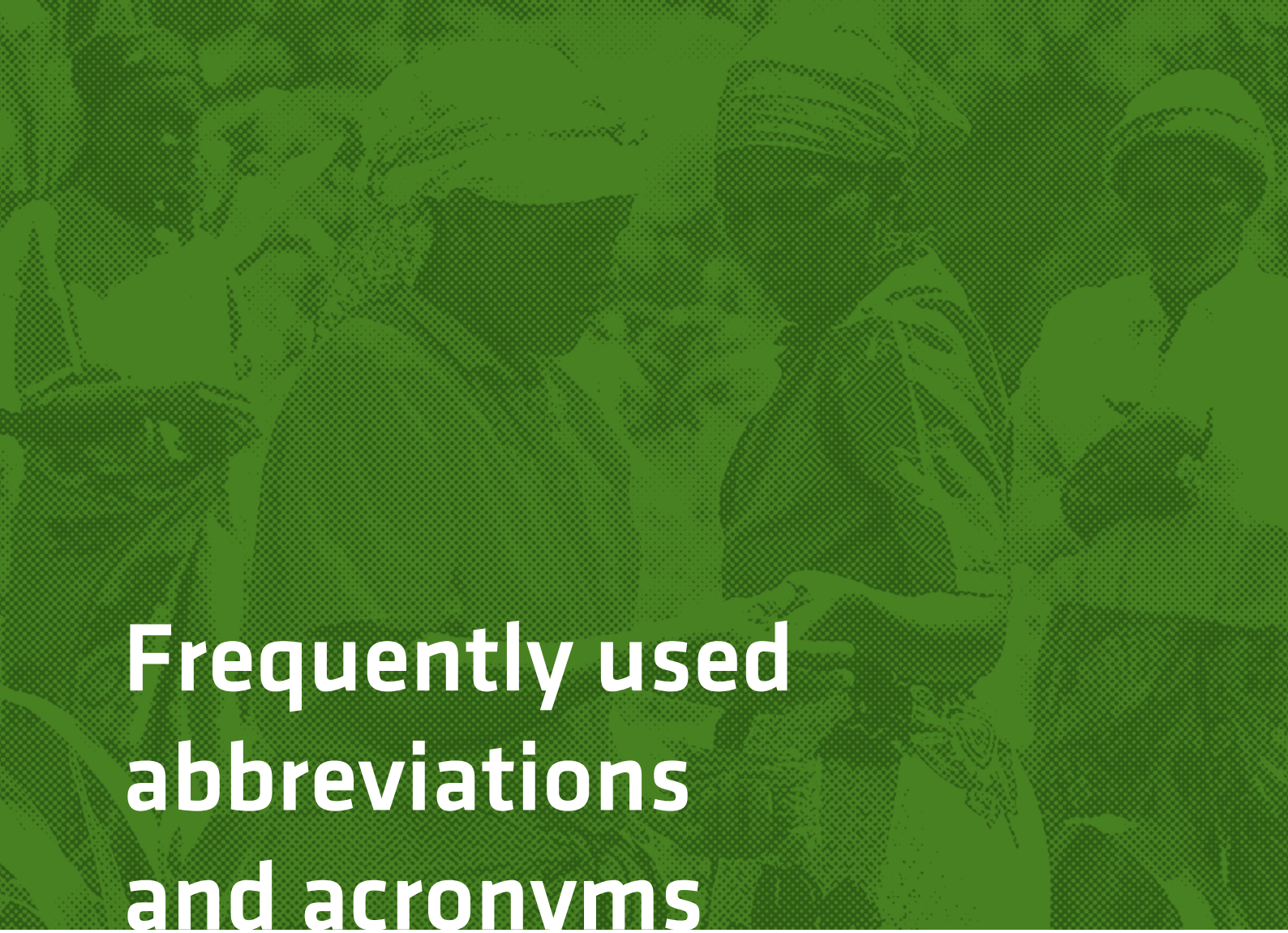
1. The Specific Marketing Standard (SMS)

The EU marketing standards apply to most fresh horticultural produce. Almost all fresh products must meet the general marketing standard (below), but the following important products are covered by the more particular specific marketing standard:

- Apples
- Citrus fruit (including oranges, soft citrus and lemons)
- Kiwi fruit
- Lettuces (including curled and broadleaved endives)
- Peaches and nectarines
- Pears
- Strawberries
- Sweet peppers
- Table grapes
- Tomatoes

2. General Marketing Standard (GMS)

The applies to most other fresh fruit, vegetables, nuts and herbs



Frequently used abbreviations and acronyms

ABBREVIATIONS

ABR	Anaerobic Baffled Reactor
ACP	African, Caribbean, and Pacific
AD	Anaerobic Digestion
BOD	Biochemical Oxygen Demand
CHP	Combined Heat and Power
C/N	Carbon to Nitrogen ratio
DM	Dry Matter
DTIE IETC	Division of Technology, Industry and Economics -International Environmental Technology Centre
DTIE – RIVU	Division of Technology, Industry and Economics – Responsible Industry and Value Chain Unit
EC	Electrical Conductivity
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organisation: UN organisation that addresses food security problems in the world
FIPS	Farm Inputs Promotion Africa
FSC	Food Supply Chain
GHG	Greenhouse Gas
GMS	General Marketing Standard
ISWM	Integrated Solid Waste Management
ISWM	International Solid Waste Management Association
IVC	In Vessel Composting
IWM	Integrated Waste Management
Kg	Kilogram
LFG	Landfill Gas
LED	Light-emitting diode
MARPOL	International convention for the prevention of pollution from ships

OSPAR	Commission dedicated to the protection and conservation of the North-East Atlantic and its resources
PCB	Polychlorinated Biphenyls
PCPB	Pesticide Control Products' Board
pH	Potential for hydrogen; a measure of acidity or alkalinity
PH	Post-harvest
PHL	Post harvest losses
PPE	Personal protective equipment
ppm	Parts per million
RPC	Returnable plastic crate
SMS	Specific Marketing Standard
SSWM	Sustainable Sanitation and Water Management
UNEP	United Nations Environment Programme
WRAPP	Waste Reduction And Purchasing Policy
WHO	World Health Organisation
WtE	Waste to Energy
ZDHC	Zero Discharge of Hazardous Chemicals
ZECC	Zero energy cool chamber

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Africa Institute:
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Basel Convention:
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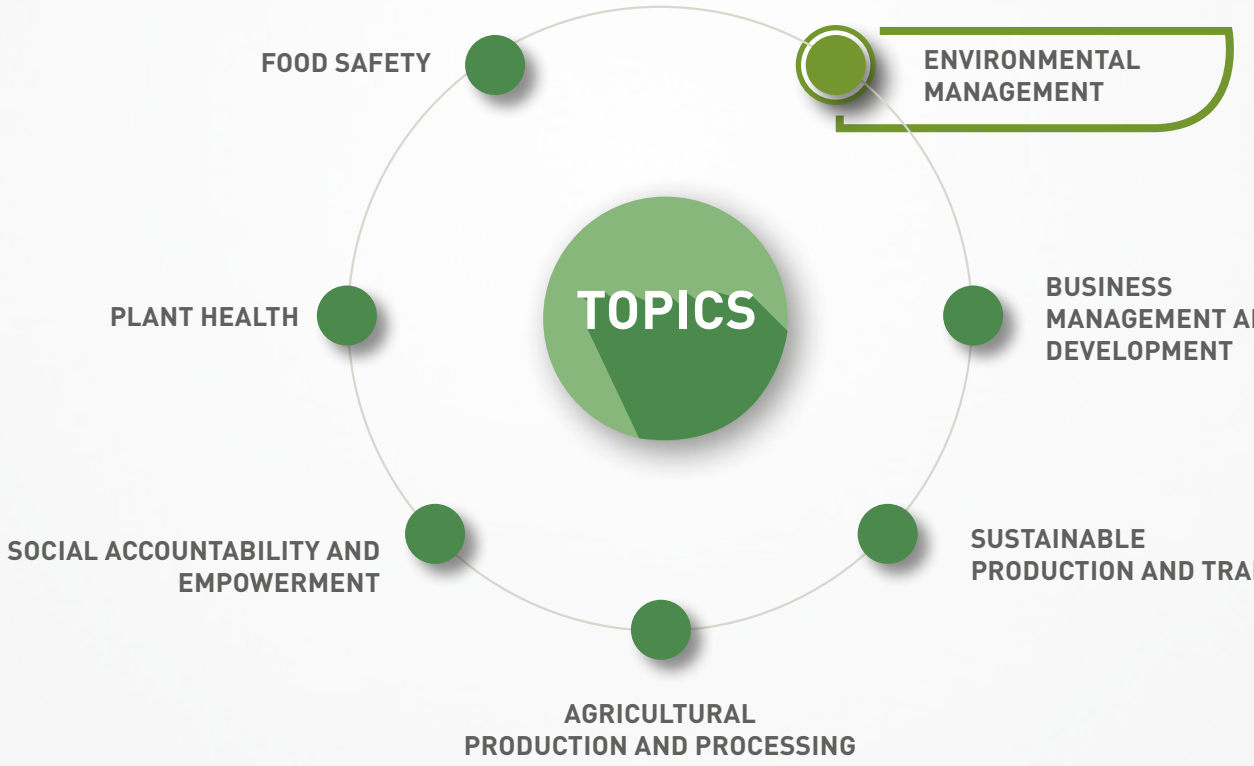

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