

Environmental, Health, and Safety Guidelines for Annual Crop Production

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)¹. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at:

www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment,

¹ Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

Applicability

The EHS Guidelines for Annual Crop Production include information relevant to large-scale, commercial production of the main annual crops, including cereals, pulses, roots and tubers, oil-bearing crops, fiber crops, vegetables, and fodder crops in temperate, subtropical, and tropical regions. Annex A contains a full description of industry activities for this sector. Plantation crops are addressed in the EHS Guidelines for Plantation Crop Production. Information applicable to the processing of crops is presented in the EHS Guidelines for Food and Beverage Processing. This document has the following sections:

Section 1.0 — Industry-Specific Impacts and Management
Section 2.0 — Performance Indicators and Monitoring
Section 3.0 — References and Additional Sources
Annex A — General Description of Industry Activities

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with annual crop production, along with recommendations for their management. Additional guidance on EHS issues that may be common across industry sectors is presented in the **General EHS Guidelines**.

1.1 Environment

Environmental issues associated with annual crop production may include the following:

- Stress on water resources
- Soil erosion and loss of productive capacity
- Pesticide use
- Eutrophication of aquatic environments
- Loss of biodiversity
- Crop residues and other solid waste
- Atmospheric emissions

Stress on Water Resources

Water management for annual crop production should aim to optimize crop yield, while conserving the quantity and quality of water resources. Surface or groundwater resources used for irrigation should be managed in accordance with the principles of Integrated Water Management consistent with the following recommendations:²

- Determine the quantity and quality of water needed for crop production;
- Evaluate the capacity of groundwater or surface water resources and collaborate with national or regional

institutions to ensure that the project considers existing or emerging plans for water management and monitoring;

- Select crops compatible with water availability;
- Maximize the use of available precipitation (“rain harvesting”), where feasible, by:
 - Reducing runoff by methods such as conservation tillage, terraces, and raised ridges that follow the land contour
 - Diverting water within the catchment area toward the crops themselves by diverting spate flow from wadis, directing runoff with low walls, and diverting flow toward crops from roads and paths to store water in the soil and reduce the effect of short dry spells
 - Storing runoff from rainy periods for use during dry spells by using tanks, ponds, cisterns, and earth dams
- Implementing irrigation water conservation measures including:
 - Reduce evaporation by avoiding midday irrigation and using trickle or drip irrigation techniques (if practical), or using ‘under canopy’ rather than overhead sprinkling
 - Reduce seepage losses in channels by lining them or using closed conduits
 - Control weeds on inter-row strips and keep them dry
 - Avoid over and under-irrigation to decrease potential for soil salinization
 - Maintain border vegetation in canals and drainage systems
 - Maintain a water management logbook that records precipitation, rainfall, and evaporation, as well as time and amounts of water applied, in order to develop an understanding of long-term trends in water use

² FAO (2002a).

Soil Erosion and Loss of Productive Capacity

Soil degradation may result from poor management especially due to excessive use of machinery and over-intensive farming practices. Soil erosion may be enhanced by heavy rainfalls, storms, and steep or long slopes, and may contribute to subsequent sedimentation of surface water bodies. Soils should be managed so as to prevent or minimize loss of productive capacity and sedimentation of surface waters. Soil loss prevention practices include:³

- Practice Integrated Nutrient Management (INM) to avoid nutrient depletion or accumulation;
- Use crops suited or adapted to the local climate and soil conditions;
- In areas with steep slopes, carefully consider planting zones and the direction of planting in relation to land contours to avoid erosion caused by precipitation or irrigation;
- Use stone barriers, vegetative cross-slope barriers, terraces, or drainage and diversion canals to prevent wind and water erosion;
- Use appropriate machinery to avoid soil compaction caused by excessively heavy equipment;
- Avoid the use of overly saline water for irrigation to prevent salinization;⁴
- Use plant cover or intercrops and shelterbelts to reduce erosion from wind and heavy rain;
- Increase the organic matter content in the soil by applying organic matter such as crop residues, compost, and manure to protect the soil physically from sun, rain, and wind and to feed soil biota. The potential for spreading of

pests should be considered before implementing this practice;

- Consider adding lime to soil to compensate for acidification, caused by acid deposition and fertilizers, and to maintain stable pH levels;
- Assess potential impacts of waste materials such as manure and sludge to soils and water resources due to the presence of contaminants (e.g. heavy metals, nitrogen, phosphorus, and diseases-causing agents) prior to use for soil enhancement.

Pesticide Use

The primary aim of pest management should be not to eradicate all organisms, but to manage pests and diseases that may negatively affect production of annual crops so that they remain at a level that is under an economically and environmentally damaging threshold. Pesticides should be managed to avoid their migration into off-site land or water environments by establishing their use as part of an Integrated Pest Management (IPM) strategy and as documented in a Pesticide Management Plan (PMP). The following stages should be considered when designing and implementing an IPM strategy, giving preference to alternative pest management strategies, with the use of synthetic chemical pesticides as a last option.

Alternatives to Pesticide Application

Where feasible, the following alternatives to pesticides should be considered:

- Provide those responsible for deciding on pesticides application with training in pest identification, weed identification, and field scouting;
- Rotate crops to reduce the presence of pests and weeds in the soil ecosystem;
- Use pest-resistant crop varieties;

³ More information can be found, for example, in the 2000 FAO [Guideline on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools](#)

⁴ See FAO (1992), chapter 4 of *The Use of Saline Waters for Crop Production*, for a discussion of the suitability of water for irrigation purposes.

- Use mechanical weed control and / or thermal weeding;
- Support and use beneficial organisms, such as insects, birds, mites, and microbial agents, to perform biological control of pests;
- Protect natural enemies of pests by providing a favorable habitat, such as bushes for nesting sites and other original vegetation that can house pest predators;
- Use animals to graze areas and manage plant coverage;
- Use mechanical controls such as traps, barriers, light, and sound to kill, relocate, or repel pests.
- Avoid the use of pesticides that fall under the World Health Organization Recommended Classification of Pesticides by Hazard Classes 1a and 1b;
- Avoid the use of pesticides that fall under the World Health Organization Recommended Classification of Pesticides by Hazard Class II if the project host country lacks restrictions on distribution and use of these chemicals, or if they are likely to be accessible to personnel without proper training, equipment, and facilities to handle, store, apply, and dispose of these products properly;
- Avoid the use of pesticides listed in Annexes A and B of the Stockholm Convention, except under the conditions noted in the convention and those subject to international bans or phaseouts;^{7 8}
- Use only pesticides that are manufactured under license and registered and approved by the appropriate authority and in accordance with the Food and Agriculture Organization's (FAO's) International Code of Conduct on the Distribution and Use of Pesticides⁹;
- Use only pesticides that are labeled in accordance with international standards and norms, such as the FAO's Revised Guidelines for Good Labeling Practice for Pesticides¹⁰;
- Select application technologies and practices designed to reduce unintentional drift or runoff only as indicated in an IPM program, and under controlled conditions;
- Maintain and calibrate pesticide application equipment in accordance with manufacturer's recommendations. Use

Pesticide Application

If pesticide application is warranted, users should take the following precautions:

- Train personnel to apply pesticides and ensure that personnel have received applicable certifications or equivalent training where such certifications are not required;^{5 6}
- Review the manufacturer's directions on maximum recommended dosage or treatment as well as published reports on using the reduced rate of pesticide application without loss of effect (such as DAAS 2000), and apply the minimum effective dose;
- Apply pesticides based on criteria such as field observations, weather data, time of treatment, and dosage, and maintain a pesticide logbook to record such information;

⁵ Examples of certification schemes are provided by the US EPA (2006), which classifies pesticides as either "unclassified" or "restricted" and requires workers that apply unclassified pesticides to be trained according to the Worker Protection Standard (40 CFR Part 170) for Agricultural Pesticides. It further requires restricted pesticides to be applied by or in the presence of a certified pesticide applicator.

⁶ Additional information on pesticide hazard classification is provided in WHO (2005).

⁷ The Stockholm Convention on Persistent Organic Pollutants (2001).

⁸ For example, the phaseout of methyl bromide by the year 2015 under the Montreal Protocol on Ozone Depleting Substances.

⁹ FAO (2002c)

¹⁰ FAO (2002c)

application equipment that is registered in the country of use¹¹;

- Establish untreated buffer zones or strips along water sources, rivers, streams, ponds, lakes, and ditches to help protect water resources
- Avoid use of pesticides that have been linked to localized environmental problems and threats.

Pesticide Handling and Storage

Contamination of soils, groundwater, or surface water resources, due to accidental spills during transfer, mixing, and storage of pesticides should be prevented by following the hazardous materials storage and handling recommendations presented in the **General EHS Guidelines**. Additional recommendations include the following:

- Store pesticides in their original packaging, in a dedicated, dry, cool, frost-free, and well aerated location that can be locked and properly identified with signs, with access limited to authorized people¹². No human or animal food may be stored in this location. The store room should also be designed with spill containment measures and sited in consideration of potential for contamination of soil and water resources;
- Mixing and transfer of pesticides should be undertaken by trained personnel in ventilated and well lit areas, using containers designed and dedicated for this purpose.
- Containers should not be used for any other purpose (e.g. drinking water). Contaminated containers should be handled as hazardous waste, and should be treated accordingly. Disposal of containers contaminated with

pesticides should be done in a manner consistent with FAO guidelines and with manufacturer's directions;¹³

- Purchase and store no more pesticide than needed and rotate stock using a "first-in, first-out" principle so that pesticides do not become obsolete.¹⁴ Additionally, the use of obsolete pesticides should be avoided under all circumstances;¹⁵ A management plan that includes measures for the containment, storage and ultimate destruction of all obsolete stocks should be prepared in accordance to guidelines by FAO and consistent with country commitments under the Stockholm, Rotterdam and Basel Conventions.
- Collect rinse water from equipment cleaning for reuse (such as for the dilution of identical pesticides to concentrations used for application);
- Ensure that protective clothing worn during pesticide application is either cleaned or disposed of in an environmentally responsible manner
- Implement groundwater supply wellhead setbacks for pesticide application and storage
- Maintain records of pesticide use and effectiveness.

Eutrophication of Aquatic Environments

Nutrient management strategies¹⁶ should aim to optimize crop yield while maintaining and improving the soil nutrient status. These strategies should be implemented as part of an INM approach that aims to prevent, reduce, or control contamination of groundwater resources and eutrophication of surface water resources from runoff and leaching of excess crop nutrients. The periods of greatest risk for runoff and leaching may be during and immediately after spreading if the nutrients are not

¹¹ Refer to host country standards for registration and certification requirement for new pesticide application equipment. Further information on registration and certification schemes is provided in FAO (2001).

¹² FAO (2002c)

¹³ See FAO Guidelines for the Disposal of Waste Pesticides and Pesticide Containers.

¹⁴ See FAO (1996).

¹⁵ See the FAO publication on pesticide storage and stock control manual. FAO Pesticide Disposal Series No. 3 (1996).

¹⁶ Roy et al. (2006)

incorporated into the soil, and during heavy rains that cause rapid runoff.

The following steps should be considered when designing and implementing an INM strategy including evaluating the need for crop nutrient application, following a recommended crop nutrient and post-nutrient application plan, and handling and storage of crop nutrients.

Evaluating the Need for Crop Nutrient Application

Consider the following to evaluate the need for, and reduce the use of, crop nutrients:

- Balance nutrient application according to INM recommendations, including the use of reduced or no soil tillage techniques, nutrient recycling, one-pass soil preparation and sowing, taking into account the potential for increased pesticide consumption;
- Use crop rotation methods to enable cultivation of leguminous plants with nitrogen fixation capabilities;
- Use plants to cover the soil, especially during a fallow period and in wet regions, to reduce loss of nutrients;
- Incorporate organic waste materials into soils rather than burning;
- Avoid excess fertilization by analyzing soil before the growing season to estimate how much additional plant nutrient will be needed for the crop to be produced. Evaluate the need for crop nutrient application through test plot observations;
- Assess soil acidity, which is important for achieving maximum uptake of phosphates;
- Provide farm operators with training in INM following published principles and agricultural practice manuals.¹⁷

¹⁷ See FAO (2000).

Crop Nutrient Application

If the application of crop nutrients is warranted, the following recommended actions to reduce environmental impacts should be considered:

- Apply organic matter, such as manure, to replace chemical fertilizers to the extent practical;
- Incorporate manure into the soil or apply between growing crops to improve plant utilization of nutrients and thereby reduce nutrient loss and contamination. Do not apply solid or liquid manure directly onto grazing areas or edible crops. In areas with intensive livestock breeding, be aware that agricultural crop lands are often used to dispose of manure with the risk of over-fertilization;
- Apply "fertigation" in horticulture, in which small amounts of fertilizer added to irrigation water may be applied. This requires detailed management and is mostly used in greenhouse production applications
- Time the application of crop nutrients using meteorological information to avoid, where feasible, application during or close to precipitation events;
- Use appropriate technical equipment for spraying manure;
- Establish buffer zones, strips, or other "no-treatment" areas along water sources, rivers, streams, ponds, lakes, and ditches to act as a filter to catch potential runoff from the land;
- Implement INM planning and documentation, which may include the use of a fertilizer logbook to record the following information:
 - Dates of purchase, dates of use, amount of fertilizer used per field / hectare, purpose of use, and weather conditions during application;
 - Rates of nutrient application for the crop growth stage;
 - Maintenance schedule of application equipment to ensure efficient dosage.

Handling and Storage of Crop Nutrients

To prevent, reduce, or control the potential contamination of soils, groundwater, or surface water resources caused by accidental spills during transfer, mixing, and storage, crop nutrients should be stored and handled in a manner consistent with the recommendations for hazardous materials management presented in the **General EHS Guidelines**. In addition, fertilizers should be stored in their original packaging and in a dedicated location that can be locked and properly identified with signs, and with access limited to authorized persons.

Biodiversity Impacts

If not properly managed, modern, intensive, conventional cultivation methods may lead to adverse impacts on biodiversity. The main ecosystem threats that should be managed at the farm level may include the following:

Loss of Genetic Resources and Variability

Personnel in charge of annual crop production operations should be aware of the biodiversity issues at the farm level (also termed agricultural biodiversity), as well as more general biodiversity issues in the area where the farm is located. The following actions should be taken to maintain farm-level agricultural biodiversity:

- Where possible, maximize reuse of residue from the previous crop on the soil surface. The potential for spreading of pests should be considered before implementing this practice;
- Reduce soil preparation to maintain the structure of soil ecosystems (e.g., promote low-till and no-till strategies);
- Utilize field borders to provide wildlife corridors around fields used for annual crop production;
- Provide buffer zones on farmland bordering wildland of specific environmental and research interest;

- Regularly monitor soil health, for example, by determining the population of soil macrofauna bioindicator species such as the earthworm population;
- Use certified crop seeds that do not contain seeds from invasive alien species and that comply with the information on the packaging regarding seed diameter and species;
- Ensure protection of the natural enemies of pests by providing favorable habitats, such as hedges, nesting sites, and original vegetation, to house pest predators; and
- Promote the use of organic agricultural practices to the extent feasible.¹⁸

The following actions should be taken to help maintain regional biodiversity:

- Before converting land to annual crop production, survey the project area to identify, categorize, and delineate natural and modified habitat types and ascertain their biodiversity value at the regional or national level;
- Ensure that any natural or modified habitat to be converted to annual crop production does not contain critical habitat, including known habitat of critically endangered or endangered species, or important wildlife breeding, feeding, and staging areas;
- Be aware of the presence of critically endangered or endangered species in the areas already used for annual crop production and consider them during management processes;
- Provide for minimum disturbance to surrounding areas when harvesting or gathering crops.

¹⁸ For further guidance on organic agriculture, see IFOAM (2005).

Genetically Modified Organisms (GMOs), Invasive Species, and Pests

Environmental concerns related to the introduction of GMO crops may include transfer of introduced genes to other species (possibly weedy or invasive), unanticipated impact on beneficial insects, or increased pest resistance. Another concern related to the introduction or export of plants and plant products is the potential for introduction of pests.

The introduction of GMO crops should be assessed for compliance with the existing host country regulatory framework for such introductions. If such a regulatory framework does not exist in the host country, the potential impacts and risks of the introduction should be assessed, paying specific attention to the potential for invasive behavior, and identifying any appropriate mitigation measures¹⁹. The potential for introduction of pests should be managed according to international standards for phytosanitary measures.²⁰

Crop Residues and Other Solid Waste

The largest volume of residues in crop production is crop residues themselves, although the waste with the most significant impact is often related to pesticide containers and obsolete, expired pesticides. Prevention and control of potential impacts from the generation of these wastes includes the following:

- Recycle crop residues and other organic materials by leaving the materials in the fields, plowing, and / or

composting. The potential for spreading of pests should be considered before implementing this practice;

- Reuse crop residues as a thermal energy fuel in bioenergy facilities, as a substrate in fermentation facilities, and as feedstock in biorefineries;
- Clean (e.g. triple rinse technique) and dispose of (e.g. through crushing, shredding, or return to suppliers) pesticide packaging and containers to ensure that they are not subsequently used as containers for food or drinking water²¹; Rinsing solutions should be recovered for reuse as diluting agents, or stored for eventual disposal, as per FAO Guideline²²
- Manage expired and unwanted pesticides as hazardous wastes in accordance with the **General EHS Guidelines** and FAO Guidelines for the management of unwanted and expired pesticides.^{23,24}

Atmospheric Emissions

Atmospheric emissions are primarily associated with emissions of fuel combustion by-products including carbon dioxide (CO₂), sulfur dioxide (SO₂), nitrogen oxide (NO_x), and particulate matter (PM), resulting from the operation of mechanized equipment or from combustion by-products from the disposal or destruction of crop residues. Dioxins and furans may be present in residues if crops have been treated with chlorinated pesticides.

Greenhouses gas (GHG) emissions, including nitrous oxide (N₂O), methane (CH₄), and ammonia (NH₃), may result from the use of fertilizers or from soil conditions associated with certain crops such as rice. Ammonia and nitrous oxide are volatilized under high wind and elevated temperature conditions.

¹⁹ Refer to host country commitments under the Convention on Biological Diversity available at <http://www.biodiv.org/default.shtml>. International standards on risk assessment are contained in the Cartagena Protocol on Biosafety (<http://www.biodiv.org/biosafety/default.aspx>).

²⁰ See the International Plant Protection Convention (<https://www.ippc.int/IPP/En/default.jsp>) and the 27 guidelines included in the International Standards for Phytosanitary Measures (2006). Also refer to the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (http://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm)

²¹ FAO (2002c).

²² FAO (2002c)

²³ FAO (1999).

²⁴ In case that disposal of pesticides involves overseas shipments, project must ensure compliance with country's commitments under Stockholm, Rotterdam and Basel Conventions.

Recommended prevention and control measures include the following:

- Manage emissions from mechanized farm equipment according to recommendations in the **General EHS Guidelines** for mobile and stationary sources;
- Where feasible, use biofuels instead of fossil energy to reduce net GHG emissions;
- Adopt reduced tillage options to increase the carbon storage capacity of soils;
- Favor solar drying techniques for crops that require drying;
- Reduce particulate matter emissions by avoiding burning straw and other organic material in the field and by maintaining organic matter to protect soil against wind erosion during and after soil preparation activities;
- Avoid unintended emissions of persistent organic pollutants (POPs) which may arise from open burning of pesticide-treated agricultural wastes avoiding such practices;
- Reduce ammonia and nitrous oxide emissions by²⁵:
 - Reducing ammonia and nitrate concentration in soil;
 - Applying denitrification inhibitors;
 - Enhancing soil aeration; and
 - Enhancing soil incorporation of ammonia and urea fertilizers and manure using techniques such as manure injection, placement of fertilizers at adequate depth beneath soil, use of supergranules in flooded rice fields, among others

1.2 Occupational Health and Safety

Occupational health and safety issues associated with annual crop production include the following:

- Physical hazards

²⁵ Roy et al. (2006)

- Confined space entry
- Chemical hazards
- Risk of fire and explosion

Physical Hazards

Machinery and Vehicles

Accidents occur in connection with the use of machines and vehicles, including tractors, harvesting machinery, and a variety of other machines on the farm. In addition, operators may be at risk of impacts associated with the noise of operating machines, especially in the more confined spaces of farm buildings, or exertion of work, which can be physically demanding and is often compounded by the presence of repetitive motion. Occupational safety and health impacts and controls relating to equipment and vehicle operation and repair are discussed in the **General EHS Guidelines**.

Confined Spaces

Occupational health and safety hazards associated with confined spaces on farms (e.g. manure pits, silos, grain bins, water tanks, or inadequately ventilated buildings) include the risk of asphyxiation, primarily due to the accumulation of methane. Entry to all confined spaces should be restricted and should be subject to permitted supervision by properly trained persons as described in the **General EHS Guidelines**.

Chemical Hazards

Exposure to pesticides

Occupational health and safety impacts associated with pesticides are similar to those for other hazardous substances, and their prevention and control are discussed in the **General EHS Guidelines**. Potential exposures to pesticides include dermal contact (e.g. in storage rooms or from leaking

containers) and inhalation during their preparation, storage, and application. The effect of such impacts may be increased by climatic conditions, such as wind, which may increase the chance of unintended drift, or high temperatures, which may be a deterrent to the use of personal protective equipment (PPE) by the operator. Recommendations specific to annual crop production include the following:

- Train personnel to apply pesticides and ensure that personnel have received the necessary certifications,²⁶ or equivalent training where such certifications are not required;
- Respect post-treatment intervals to avoid operator exposure during reentry to crops with residues of pesticides;
- Respect preharvest intervals to avoid operator exposure to pesticide residues on products during harvesting;
- Ensure hygiene practices are followed (in accordance to FAO and PMP) to avoid exposure of family members to pesticides residues.

Exposure to Organic Dust

Threshing, handling, and storage of grain generate potentially high concentrations of organic dust, including particles from grain, fungi, and bacteria, as well as inorganic material. Many agricultural jobs can expose workers to dust including, for example, cleaning silos, dryers, and grain hoppers, and threshing and milling feed grain. Acute toxic alveolitis, otherwise known as organic dust toxic syndrome, can accompany brief, occasional exposures to heavy concentrations of organic dust in

an agricultural environment. Some dust, especially dust from moldy forage, grain, or hay, carries antigens that can cause severe irritation to the respiratory tract. Breathing dust from moldy feed materials can result in a permanent lung condition commonly known as "Farmer's lung".

Occupational health and safety impacts associated with nuisance dust in agricultural settings are similar to those for other industries and their prevention and control are discussed in the **General EHS Guidelines**. In addition, recommendations for dust control specific to annual crop production include the following:

- Use local air extraction devices at dust-generating equipment, such as tipping pits, elevators, open conveyors, hoppers, silos, dryers, and scales;
- Equip threshing machines with a cab and ventilator;
- Store only dry grain (and dry, well-cured forages and hay) to reduce microorganism growth.

Risk of Fire and Explosion

Grain storage elevators present a risk of explosion given the presence of powdered grain and the potential for explosive atmospheres. Potential ignition sources for the grain dust may include the mechanical malfunction or deterioration of concentrators, including seizing of roller bearings. Among the recommended methods for prevention of explosions in grain storage facilities are the prevention of accumulation of grain dust through maintenance and repair of dust control systems and the maintenance of grain elevator equipment.²⁷

²⁶The US EPA classifies pesticides as either "unclassified" or "restricted." All workers that apply unclassified pesticides must be trained according to the Worker Protection Standard (40 CFR Part 170) for Agricultural Pesticides. Restricted pesticides must be applied by or in the presence of a certified pesticide applicator. For more information, see <http://www.epa.gov/pesticides/health/worker.htm>

²⁷ Additional information on the prevention of grain elevator explosion hazards is provided by the United States National Fire Prevention Association (www.nfpa.org)

1.3 Community Health and Safety

Community health and safety issues during the production of annual crops may include the following:

- Potential exposure to pesticides caused by spray drift, improper disposal and use of packaging and containers, and the presence of pesticides in potentially harmful concentrations in postharvest products;
- Potential exposure to pathogens and obnoxious odors associated with the use of manure;
- Potential exposure to air emissions from open burning of crop waste.

Pesticides may affect community health in the same ways that they affect individual operators, through dermal contact or through inhalation of such chemicals as a result of application as well as through potential contamination of potable water sources. The potential for community exposure to pesticides in the environment may be considerably influenced by climatic conditions, such as wind velocity, while the potential for exposure to residual levels in post-harvest products may depend on adherence to pesticide use instructions. There may also be a risk to the community caused by dermal contact with residues in containers, packaging, etc. While odors from manure, especially during application, are not generally hazardous, they can be a serious source of discomfort to the community. Open burning of residual organic crop waste can result in degradation of air quality for surrounding communities.

Specific recommendations include the following:

- Avoid the aerial application of pesticides whenever feasible;
- Use biological or safe products, whenever feasible;

- Respect pre-harvest intervals for pesticides to avoid unacceptable levels of pesticide residues in products, further complying with any applicable pesticide tolerance requirements;²⁸
- Do not store or transport pesticides and fertilizers with food or beverages (including drinking water);
- Ensure that animals and unauthorized people are not present in the areas where pesticides are handled or applied;
- Store manure as far away from dwellings as possible, and use measures, such as covering the manure, to reduce odors and atmospheric emissions;
- Do not apply manure to the fields if the wind direction is toward nearby dwellings.
- Clean (e.g., a triple rinse or pressure technique) and dispose of (e.g., through crushing, shredding, or return to suppliers) pesticide packaging and containers to ensure that they are not subsequently used as containers for food or drinking water;
- Open burning of residual, organic crop waste should be avoided. Crop waste should be returned to the fields to enhance the nutrient content of the soil. Opportunities for use of crop waste as a fuel for energy generation should be considered, where feasible, including composting to generate biogas.

²⁸ Examples of potentially applicable pesticide tolerance requirements include the FAO/WHO (1962–2005) Codex Alimentarius' Maximum Residue Limits in Foods and 40 CFR Part 180, Tolerances and Exemptions from Tolerances for Pesticide Chemicals in Food, the latter of which applies to crops sold in the United States.

2.0 Performance Indicators and Monitoring

2.1 Environment

The following environmental guidelines in Table 1 should be used in applying pesticides and nutrients in order to avoid or reduce leaching into groundwater or surface water, runoff into surface water, atmospheric emissions, and other losses outside of the crop production system. Additional guidance on quantitative parameters that can be used to help establish a project's nutrient balance is presented in **Annex B**. Guidance on quantitative parameters that can be used to establish a project's water consumption can be found in **Annex C**.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. This may include parameters such as water quality, including water used for irrigation; soil quality; and pesticide and crop nutrient use among others. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored.

Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

Table 1. Water / soil / produce quality guidelines

Parameter	Media	Guideline Value
Pesticides, nitrates, coliform or other potential agricultural contaminants	Irrigation water	Concentrations should not exceed national irrigation water quality standards or, in their absence, internationally recognized guidelines (e.g. WHO Water Guidelines applicable to irrigation water quality) ^a
Pesticides, nitrates, coliform or other potential agricultural contaminants	On-site water supplies	Concentrations should not exceed national drinking water quality standards or, in their absence, internationally recognized guidelines (e.g. WHO Irrigation or Drinking Water Guidelines for compounds potentially present in on-site groundwater wells or surface waters) ^b
Nutrient balance	On-site soil	Nutrient surpluses should remain stable; nitrogen surplus should be preferably below 25kg/ha/yr ^c
Pesticides	On-site soil and produce	Below applicable tolerance levels ^d

NOTES:

^aWHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 2: Wastewater Use in Agriculture
http://www.who.int/water_sanitation_health/wastewater/qsuweg2/en/index.html

^bWHO Guidelines for Drinking Water Quality
http://www.who.int/water_sanitation_health/dwg/en/

^cAgriculture Indicator Fact Sheet, European Environment Agency, Nitrogen surplus from agricultural land, 2001.
http://themes.eea.europa.eu/Sectors_and_activities/agriculture/indicators/nutrients/nutrients.pdf

See also Roy et al. (2006) Plant nutrition for food security, a guide for integrated nutrient management.

^dExamples of potentially applicable pesticide tolerance requirements include the Food and Agriculture Organization *Codex Alimentarius* Maximum Residue Limits in Foods and the US Code of Federal Regulations Title 40, Part 180 — Tolerances and Exemptions from Tolerances for Pesticide Chemicals in Food, the latter of which applies to crops sold in the United States.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV[®]) occupational exposure guidelines and Biological Exposure Indices (BEIs[®]) published by American Conference of

Governmental Industrial Hygienists (ACGIH),²⁹ the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),³⁰ Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),³¹ Indicative Occupational Exposure Limit Values published by European Union member states,³² or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)³³.

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals³⁴ as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

²⁹ Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

³⁰ Available at: <http://www.cdc.gov/niosh/npg/>

³¹ Available at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

³² Available at: http://europe.osha.eu.int/good_practice/risks/ds/oe/

³³ Available at: <http://www.bls.gov/iif/> and
<http://www.hse.gov.uk/statistics/index.htm>

³⁴ Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

3.0 References and Additional Sources

Danish Agricultural Advisory Service (DAAS). 2000. Manuals of Good Agricultural Practice from Denmark, Estonia, Latvia, and Lithuania. DAAS. Available at <http://www.lr.dk/international/informationsserier/intfbdiv/cgaps.htm>

DAAS. 2006a. J.E. Olesen. Sådan reduceres udledningen af drivhusgasser fra jordbruget (How to Reduce Greenhouse Gas Emissions from Agriculture). DAAS. Available at http://www.lr.dk/planteavl/informationsserier/info-planter/PLK06_07_1_3_J_E_Olesen.pdf

DAAS. 2006b. Søren O Petersen: Emission af drivhusgasser fra landbrugsjord (Emission of Greenhouse gases from agriculture). DAAS. Available at http://www.lr.dk/planteavl/informationsserier/info-planter/PLK06_07_1_1_S_O_Petersen.pdf

Danish Ministry of Foreign Affairs (Danida). 2002. Assessment of Potentials and Constrains for Development and Use of Plant Biotechnology in Relation to Plant Breeding and Crop Production in Developing Countries. Working Paper. Copenhagen: Danida.

Danish Ministry of Environment and Energy and Danish Ministry of Food, Agriculture and Fisheries. 2000. Pesticide Action Plan II. Copenhagen: Ministry of Environment and Energy and Ministry of Food, Agriculture and Fisheries Available at <http://www.mim.dk/>

European Commission (EC). 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy. Brussels: EC. Available at http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32000L0060&model=quichett

European Commission (EC). 2006. Biotechnology. Brussels: European Commission, Health and Consumer Protection DG. Brussels: EC. Available at http://europa.eu.int/comm/food/food/biotechnology/index_en.htm

EEC (European Economic Communities). 1986. [Council Directive 86/362/EEC](#), Council Directive 86/362/EEC of 24 July 1986 on the Fixing of Maximum Levels for Pesticide Residues in and on Cereals. Brussels: EEC. Available at <http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:31986L0362:EN:HTML>. Consolidated text 2004: http://europa.eu.int/eur-lex/en/consleg/pdf/1986/en_1986L0362_do_001.pdf

EEC. 1990. Council Directive of 27 November 1990 on the Fixing of Maximum Levels for Pesticide Residues in and on Certain Products of Plant Origin, including Fruit and Vegetables (90/642/EEC). Consolidated text 1990L0642 22/07/2003: EEC. Brussels: EEC. Available at http://europa.eu.int/eur-lex/en/consleg/pdf/1990/en_1990L0642_do_001.pdf

EEC. 1991. Council Directive of 12th December 1991 Concerning the Protection of Waters Against Pollution Caused by Nitrates from Agricultural Sources 91/676/EEC. Consolidated in 1991L0676 — 20/11 2003. Brussels: EEC. Available at http://europa.eu.int/eur-lex/en/consleg/pdf/1991/en_1991L0676_do_001.pdf

EEC. 1999. Council Directive 91/414/EEC of 15 July 1991 Concerning the Placing of Plant Protection Products on the Market. Consolidated in CONSLEG

1991 L0414 — 01/01 2004. Brussels: EEC. Available at http://europa.eu.int/eur-lex/en/consleg/pdf/1991/en_1991L0414_do_001.pdf

European Food Safety Authority (EFSA). Available at http://europa.eu.int/comm/food/index_en.htm

EurepGAP. 2004. Control Points and Compliance Criteria: Fruit and Vegetables. Version 2.1. Euro-Retailer Produce Working Group (EUREP) for the global certification of Good Agricultural Practices (GAP). Cologne: EurepGap. Available at <http://www.eurep.org/>

European Agency for Safety and Health at Work. 2006. Available at <http://europe.osha.eu.int/OSHA> FAO (Food and Agriculture Organization of the United Nations). 1990. Guidelines on Personal Protection When Using Pesticides in Hot Climates. Rome: FAO. Available at <http://www.fao.org/AG/AGP/AGPP/Pesticid/>

Food and Agriculture Organization of the United Nations (FAO) Committee on Agriculture. 2001. Biosecurity in Food and Agriculture, Sixteenth Session, Rome, March 26–30, 2001, Item 8 of the Provisional Agenda. Rome: FAO. Available at <http://www.fao.org/DOCREP/MEETING/003/X9181E.HTM>

FAO. 1992. The Use of Saline Waters for Crop Production — FAO Irrigation and Drainage Paper 48. Rome: FAO. Available at <http://www.fao.org/docrep/T0667E/t0667e07.htm>

FAO. 1995. Revised Guidelines on Good Labeling Practice for Pesticides. Rome: FAO. Available at <http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/r.htm>

FAO. 1996. Pesticide Storage and Stock Control Manual. FAO Pesticide Disposal Series N°3. Rome: FAO. Available at http://www.fao.org/AG/AGP/AGPP/Pesticid/Disposal/index_en.htm http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/V8966E/V8966E00.htm

FAO. 1999. Guidelines for the Management of Small Quantities of Unwanted and Obsolete Pesticides. FAO Pesticide Disposal Series N°7. Rome: UNEP/WHO/FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/X1531E/X1531E00.htm

FAO. 2000. Guideline and Reference Material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools. AGL/MISC/27/2000. Rome: FAO, Land and Plant Nutrition Management Division. Available at <http://www.fao.org/organicag/frame2-e.htm> <ftp://ftp.fao.org/agl/agll/docs/misc27.pdf>

FAO. 2001. Guidelines on Procedures for the Registration, Certification and Testing of New Pesticide Equipment. Available at: <http://www.fao.org/docrep/006/Y2683E/Y2683E00.HTM#1>

FAO. 2002a. Crops and Drops: Making the Best Use of Water for Agriculture. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y3918E/Y3918E00.HTM

FAO. 2002b. Fertilizer Use by Crop, fifth edition. Rome: FAO. Available at <http://www.fertilizer.org/ifa/statistics/crops/fubc5ed.pdf>

FAO. 2002c. International Code of Conduct on the Distribution and Use of Pesticides (revised version November 2002). Rome: FAO. Available at <http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/Code/Download/Code.doc>

FAO. 2002d. World Soil Resources Report 101. Biological Management of Soil Ecosystems for Sustainable Agriculture. Rome: FAO. Available at http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/006/Y4810E/Y4810E00.HTM

FAO. 2003a. Technical Report No 2: Environmental and Social Standards, Certification and Labeling for Cash Crops. Rome: FAO. Available at <http://www.fao.org/organicag/>

FAO. 2003b. Weighing the GM Arguments For and Against. Rome: FAO. Available at <http://www.fao.org/english/newsroom/focus/2003/gmo7.htm>

FAO. 2005. Organic Agriculture at FAO. Rome: FAO. Available at <http://www.fao.org/organicag/>

FAO. 2006. Best Practices Website. Rome: FAO. Available at http://www.fao.org/bestpractices/index_en.htm?jsessionid=9CC6A87219AC13C83A7DA1479E055C66

Food and Agriculture Organization of the United Nations, Land and Water Division (FAO AGL). 1991. Water Harvesting — A Manual for the Design and Construction of Water Harvesting. Training Manual No. 3 in Water harvesting (AGL/MISC/17/91). Rome: FAO AGL. Available at www.fao.org/docrep/u3160e/u3160e00.htm

FAO AGL. 2002a. Crop Water Information. Rome: FAO AGL. Available at <http://www.fao.org/ag/AGL/AGLW/cropwater/cwinform.stm>

FAO AGL. 2002b. CROPWAT — A Computer Program for Irrigation Planning and Management. Bangladesh: Sustainable Development Networking Programme (SDNP). Rome: FAO AGL. Available at <http://www.sdnbd.org/sdi/issues/agriculture/database/CROPWAT.htm>

FAO AGL. 2003. CLIMWAT: A Climatic Database for CROPWAT. Rome: FAO AGL. Available at <http://www.sdnbd.org/sdi/issues/agriculture/database/CROPWAT.htm>

FAO and World Health Organization (WHO). 1962–2005. Codex Alimentarius. Geneva: FAO and WHO. Available at http://www.codexalimentarius.net/web/index_en.jsp

Helsinki Commission (Helcom). 2004. The Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992, Article 5 and Annex 1: Harmful Substances and Article 6: Principles and Obligations Concerning Pollution from Land-based Sources. Helsinki: Helsinki Commission. Available at <http://www.helcom.fi/stc/files/Convention/Conv0704.pdf>

International Federation of Organic Agriculture Movements (IFOAM). 2005. IFOAM Basic Standards for Organic Production and Processing (Version 20 May 2005). Bonn: IFOAM. Available at www.ifoam.org and http://www.ifoam.org/about_ifoam/standards/norms.html

International Labour Organization (ILO). 2000a. International Labour Conference, Report VI, Safety and Health in Agriculture. Geneva: ILO. Available at <http://www.ilo.org/public/english/standards/relm/ilc/ilc88/rep-vi-1.htm#CHAPTER%20IV>

ILO. 2000b. ILC88 — Report of the Director-General: Activities of the ILO, 1998–99. Chapter 3: Protecting Working People. Geneva: ILO. Available at <http://www.ilo.org/public/english/standards/relm/ilc/ilc88/rep-1a-3.htm>

Institute of Soil Science and Plant Cultivation. 1999. Polish Code of Good Agricultural Practice. ISBN-83-88031-02-3. In cooperation with Danish Agricultural Advisory Centre and co-financed by the Danish EPA. Pulawy: Institute of Soil Science and Plant Cultivation.

Inter-Organization Programme for the Sound Management of Chemicals (IOMC). 2002. Reducing and Elimination of the Use of Persistent Organic Pesticide. Geneva: IOMC and UNEP. Available at <http://www.chem.unep.ch/pops/pdf/redelipops/redelipops.pdf>

Louisiana Department of Environmental Quality. Nonpoint Source Pollution Program, Agricultural Best Management Practices. Baton Rouge, LA: Department of Environmental Quality. Available at <http://nonpoint.deq.louisiana.gov/wqa/default.htm>

Roy, R.N., A. Finck, G.J. Blair and H.L.S. Tandon. 2006. Plant Nutrition for Food Security, A Guide for Integrated Nutrient Management. FAO Fertilizer and Plant Nutrition Bulletin 16. Available at <ftp://ftp.fao.org/aq/aql/docs/fpnb16.pdf>

Soil Association. 2006. GM/Genetic Engineering. Bristol: Soil Association. Available at <http://www.soilassociation.org/gm>

Stockholm Convention on Persistent Organic Pollutants. 2001. Available at <http://www.pops.int/>

United Kingdom Department for Environment, Food and Rural Affairs (DEFRA). 2004. Pesticides and Integrated Farm Management. London: Department for Environment, Food and Rural Affairs. London: DEFRA. Available at http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/Pesticides_Forum/PesticidesandIFM.pdf

United Kingdom Health and Safety Executive (HSE). 2005a. Fatal Injuries Report 2004/05. Fatal Injuries in Farming, Forestry and Horticulture. Part 2: Analysis of Reportable Fatal Injuries in the Agricultural Sector, 1994/95–2003/04, p. 23. London: HSE. Available at <http://www.hse.gov.uk/agriculture/pdf/fatal0405.pdf>

UK HSE. 2005b. Fatal Injuries Report 2004/05. Fatal Injuries in Farming, Forestry and Horticulture. Part 3: Non-Fatal Injuries in the Agricultural Sector, 1994/95–2003/04, pp. 42–46. London: HSE. Available at <http://www.hse.gov.uk/agriculture/pdf/fatal0405.pdf>

United Nations Environmental Programme (UNEP). 1992. Convention on Biological Diversity. Montreal: Secretariat of the Convention on Biological Diversity UNEP. Available at <http://www.biodiv.org/convention/default.shtml>

US Environmental Protection Agency (EPA). 2006b. Pesticides: Health and Safety, Worker Safety and Training. Washington, DC: US EPA. Available at <http://www.epa.gov/pesticides/health/worker.htm>

US EPA. National Agriculture Compliance Assistance Center. 2006a. Agriculture Centre, Ag 101. Washington, DC: US EPA. Available at <http://www.epa.gov/agriculture/ag101/index.html>

World Health Organization (WHO). 2005. The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification: 2004. Geneva: WHO. Available at http://www.who.int/ipcs/publications/pesticides_hazard/en/index.html and http://www.who.int/ipcs/publications/pesticides_hazard_rev_3.pdf

Annex A: General Description of Industry Activities

Cultivation of annual crops in developing countries is characterized by a wide range of crops, soil types, and climatic conditions. Modification of the environment varies from minimal to intensive. Land use, production levels, and associated costs reflect these and other parameters. The land areas used for production may vary from a few to many hundreds of hectares.

Modern machinery gives farmers the opportunity to farm greater areas. The tractor, a central tool in crop production, provides power to implement crop production and handling operations. Tractors are most often used to pull equipment through the field and to provide power to rotate equipment components—called power takeoff (PTO). A modern farm tractor is usually equipped with a diesel engine with an output ranging from less than 40 to more than 400 PTO horsepower.³⁵

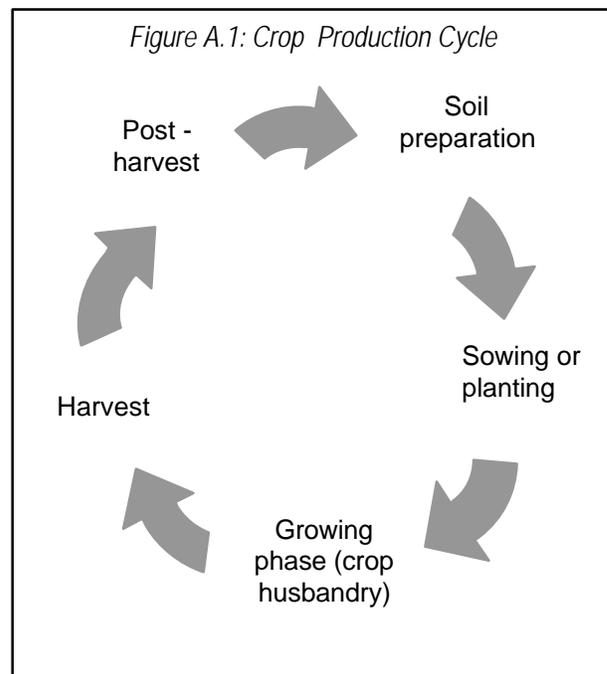
The lifetime of annual crops is, by definition, one year or at least one growing season. More than one crop may be produced on the area during one year. However, a single crop is just one cycle of production for a business, which continues for many years with occasional periods of fallow or rejuvenation determined by nutrient management and economic considerations. Typically, post harvest operations lead straight to the next field preparation phase. The production cycle is illustrated in figure A-1, and each step is described below as it applies to grain production.

Soil Preparation

Before planting, the soil needs to be prepared to manage the weed plants in the seedbed. In most farming systems, weeds

are managed by tillage and herbicide application. Tillage can occur anytime between harvest of the previous year's crop and planting of the new crop. The three main tillage methods vary according to the amount of crop residue they leave on the surface, as summarized in Table A-1. Crop residue is an important factor because it slows runoff from agricultural land.

Farmers may rely on pesticides for weed control under all tillage systems, and the amount of pesticide used is more or less independent of tillage method. Organic farming systems use the same variety of tillage methods for soil preparation but do not use herbicides. In organic operations, weeds may be removed manually or mechanically, and a certain amount of weed coverage may be tolerated by the operator.



³⁵ Additional information and examples of temperate climate farming systems is provided in the US EPA's Agricultural Centre Web site provides an overview of the crop production cycle as well as a breakdown of the machinery used at each stage. See <http://www.epa.gov/agriculture/ag101/index.html>

Table A-1. Tillage Methods

Tillage Method	Description	Residue Coverage
Conventional Tillage	Primary tillage with moldboard plow before planting, followed by secondary tillage and mechanical cultivation after the crop is up	< 15%
Reduced Tillage	Tillage without inverting the soil layer, typically using chisel plow	15% - 30%
Conservation Tillage	No till (herbicide applied directly on last season's crop residue), strip till (only the narrow strip used for the crop row is tilled), ridge till (ridges on which the crop is planted are formed during cultivation or after harvest and maintained from year to year in the same location), and mulch till (full-width tillage that disturbs all of the soil surface but retains most of the residue on the land surface).	>30%

Sowing and Planting

Sowing and planting ideally take place right after tillage to reduce soil erosion. The main equipment used in sowing includes tractor-drawn drills and planters, which open a furrow, meter and deliver the seeds, and cover the seed with soil. Some planters can cut through residues and till small strips of soil in each row at the time of planting. Planters can also be equipped to apply fertilizer and pesticides during planting.

Crop Husbandry

The main activities in crop husbandry include nutrient management, pest management, and integrated water management.

Nutrient Management

When applied in proper quantities and at appropriate times, nutrients—especially nitrogen (N), phosphorus (P), and potassium (K)—help achieve optimum crop yields.³⁶ Nutrient management is the practice of using nutrients wisely for

optimum economic benefit taking into account costs for fertilizers and revenues from crops, and while minimizing negative impacts on the environment.³⁷

N, P, and K plant nutrients can be applied to the soil in the form of chemical fertilizers, manure, and sewage sludge using spreaders or sprayers. Common nitrogenous chemical fertilizers include anhydrous ammonia, urea, ammonium nitrate and urea solutions, and ammonium nitrate. The use of synthetic nitrogenous fertilizers is prohibited in organic agriculture; alternatives include mineral fertilizers and manure, which is why organic farms often integrate crop and livestock production.

Pest Management

Pesticides include herbicides used to manage unwanted weed species, fungicides to manage fungal diseases, insecticides to manage insect pests, and acaricides to manage mites. The application of pesticides, in general, is not an option for organic agricultural operations. Instead, alternative biological and physical means are used to prevent unacceptable losses from pests, for example, the release of pest predators and parasites.

Water Management

Water may be applied during the production cycle depending on crop needs and the climatic conditions during the growth phase. When used for irrigation, water may be applied in many ways, such as drip irrigation (including the application of a water-fertilizer mix known as "fertigation"), open canal irrigation, simple sprinklers, or large scale irrigation machines, which are stationary or move through the crops, as well as other variations.

³⁶ Roy et al. (2006)

³⁷ US EPA (2006), Ag 101.

Harvest

Field crops are often harvested by machine, while other crops may be picked manually. Mechanized equipment is usually used to harvest grain and seed crops. The major functions performed by a combine include cutting and gathering, feeding, threshing, separating, cleaning, and grain-handling operations in the field.

Postharvest Storage and Processing

Postharvest storage and processing of crops includes removing unwanted fractions of the product, such as cereal glumes and

outer leaves of vegetables; sorting; washing to remove soil or other contaminants that reduce product quality; drying, either in the field or in farm buildings; and storage. Postharvest storage and processing may require the application of pesticides to storage locations or to the product itself to prolong its shelf life. Machinery to transport the crop product into and out of storage includes belts and augers, as well as tractors with various attachments. Storage buildings can vary from simple sheds and silos to large and complex containers with controlled temperature, humidity, and air quality.

Annex B: Nutrient Consumption

Using a fertilizer logbook, farmers should document the use of each nutrient. Table B-1 presents examples of the average uptake of nutrients by selected plant species. Nitrogen, phosphorus, and potassium quantities should be expressed as pure substances, because the actual weight of pure substances used in the product varies among different commercial products. It is important to recycle the nutrients present in crop residues. The nutrient content of selected crop residues is presented in table B-2.

Table B-1. Examples of Nutrient Uptake by Selected Annual Crops

Annual Crop ^a	Nutrients in yield (kg/100 kg) ^b			
	Nitrogen N	Phosphorus P ₂ O ₅	Potassium K ₂ O	Magnesium MgO
Cereals	2.30-3.15	0.94-1.37	1.88-3.62	0.30-0.46
Rape	4.61	2.11	5.56	0.70
Leguminous plants	5.70-7.80 ^c	1.35-2.04	3.08-3.85	0.53-0.83
Potato and fodder beetroot	0.31	0.10-0.15	0.42-0.79	0.02-0.11
Sugar beetroot	0.54	0.20	0.85	0.12
Silage maize	0.38	0.14	0.70	0.08
Lucerne, clover	0.80	0.16	0.70	0.08
Mixtures for green fodder	0.40	0.14	0.60	0.05

NOTES:
^a Polish Code of Good Agricultural Practice, Institute of Soil Science and Plant Cultivation Pulawy 1999 ISBN-83-88031-02-3. In cooperation with Danish Agricultural Advisory Centre and co-financed by the Danish EPA.
^b With appropriate bulk of by-products
^c Nitrogen fixed by Rhizobium from the atmosphere

Table B-2. Nutrient Residues in Selected Annual Crops^a

Annual Crop	Amount produced	Nutrient Content (kg / ton)		
		Nitrogen N	Phosphorus P	Potassium K
Maize stover	3 t /ha	10	2	12
Rice straw	1.5 t /ha	4.7	0.7	12
Wheat straw	1 t / ha	3	0.8	14

NOTE:
^a FAO (Food and Agriculture Organization of the United Nations). 2000. Guideline and reference material on integrated soil and nutrient management and conservation for farmer field schools. AGL/MISC/27/2000. Rome: Food and Agriculture Organization of the United Nations, Land and Plant Nutrition Management Division. <ftp://ftp.fao.org/agl/agll/docs/misc27.pdf>

Annex C: Water Consumption

Water consumption per crop can be calculated and compared with a theoretical standard value. In practice, the requirements for irrigation water depend on crop species, soil type, evaporation, and water conservation practices. The Food and Agriculture Organization provides guidance on water management and how to calculate appropriate irrigation. CROPWAT³⁸ is a practical tool for the personal computer that can complete standard calculations for evapotranspiration and crop water requirements and crop irrigation requirements and, more specifically, design and manage irrigation schemes.

It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain-fed conditions or deficit irrigation. Calculations of crop water requirements and irrigation requirements are carried out with inputs of climatic and crop data. Standard crop data are included in the program and climatic data can be obtained for 144 countries through the CLIMWAT database.³⁹ Examples of water requirements of individual crops and typical yields and efficiencies are presented in table C-1.

Table C-1. Water Consumption by Selected Annual Crops

Annual Crop	Crop water need ^b (mm in total growing period)	Typical yield and efficiency ^a
Beans	300 - 500	Good commercial yield in favorable environments under irrigation is 6 - 8 ton/ha fresh and 1.5 - 2 ton/ha dry seed. The water utilization efficiency for harvested yield (Ey) for fresh beans containing 80 - 90% moisture is 1.5 - 2.0 kg/m ³ and for dry beans containing about 10 % moisture is 0.3 - 0.6 kg/m ³
Cotton	700 - 1300	A good yield of a 160 - 180 day cotton crop under irrigation is 4 - 5 ton/ha seed cotton of which 35 % is lint. Water utilization efficiency for harvested yield (Ey) for seed cotton containing about 10 % moisture is 0.4 - 0.6 kg/m ³ .
Maize	500 - 800	Under irrigation a good commercial grain yield is 6 to 9 ton/ha (10 - 13 % moisture). The water utilization efficiency for harvested yield (Ey) for grain varies then between 0.8 and 1.6 kg/m ³ .
Sorghum/ Millet	450 - 650	A good yield under irrigation is 3.5 - 5 ton/ha (12 - 15 % moisture). The water utilization efficiency for harvested yield (Ey) for grain is between 0.6 and 1.0 kg/m ³
Soybean	450 - 700	Yield can vary widely with water availability, fertilization and row spacing. Under rain-fed conditions, good soybean yields vary between 1.5 and 2.5 ton/ha seed. High yields of improved varieties are between 2.5 and 3.5 ton/ha seed under irrigation. The water utilization efficiency for harvested yield (Ey) for seed containing 6 - 10 % moisture is 0.4 - 0.7 kg/m ³ .
Sunflower	600 - 1000	The giant varieties, grown for poultry feeding and human consumption because of their low oil content, produce seed yields in the range of 0.8 - 1.5 ton/ha under rain-fed conditions. The seeds of dwarf and semi-dwarf varieties contain 25 - 35 % oil and give a total yield similar to the giant varieties. New Russian varieties with seeds of low hull content have an oil-content of up to 50 %. Under irrigation seed yields of 2.5 - 3.5 ton/ha are commonly obtained. The water utilization efficiency for harvested yield (Ey) for seeds containing 6 - 10 % moisture is 0.3 - 0.5 kg/m ³
Potato	500 - 700	Good yields under irrigation of a crop of about 120 days in the temperate and subtropical climates are 25 - 35 ton/ha fresh tubers and in tropical climates yields are 15 - 25 ton/ha. The water utilization efficiency for harvested yield (Ey) for tubers containing 70 - 75 % moisture is 4 - 7 kg/m ³
Wheat	450-650 - (for high yields)	A good yield of wheat under irrigation is 4 - 6 ton/ha (12 - 15 % moisture). The water utilization efficiency for harvested yield (Ey) for grain is about 0.8 - 1.0 kg/m ³ .
NOTES: ^a FAO (2002 a) ^b FAO AGL (1991)		

³⁸ FAO AGL (2002b).

³⁹ FAO AGL (2003).