25. Ports and harbours, port construction and operations

Contents

1. Scope

The ports and harbours sector includes all those activities undertaken in seaports to ensure the safe **transfer, intermediate storage and intermediate transport** of **solid, liquid and gaseous goods** of all kinds in the course of **onward forwarding of these goods to and from land vehicles and vessels,** or the transport of persons (e.g. ferry ports), or the landing of foodstuffs (e.g. fishing ports); these are the **primary functions** of a harbour.

Land vehicles Vessels

Rail vehicles Sea-going vessels, ferries
Road vehicles Fishing vessels
Inland water vessels Underwater pipelines
Pipelines

All harbours furthermore have the function of a "safe haven".

The subsector of "**seaport infrastructure**" encompasses all the **land-side and water-side installations** of a seaport, which are directly or indirectly required to **perform the primary function** of a seaport, or which may be established **in the form of industrial, commercial, or service facilities, i.e.** to perform **secondary functions.**

Land-side facilities include:

- roads, railway lines and other transport areas;
- storage and stacking areas, warehouses and silo installations, tank farms,

crane tracks;

- bridges, underpasses and overpasses, pipelines etc.;
- supply and disposal systems (for water, power, wastewater, refuse, bilgewater, oil, used oil);
- flood defences, dykes etc. (in harbours exposed to high-water and flood risks);
- operational buildings such as administration, equipment and repair facilities;
- industrial installations and buildings for harbour-related and secondary industries including e.g. wharf installations and buildings.

Water-side facilities include:

- harbour basins, approaches, access channels, locks, harbour dams, breakwaters;
- goods transfer quays and piers, shoreline protection, ro-ro and ferry facilities, dolphins and landing bridges;
- shipbuilding berths and fitting quays of wharfs (if located in the port area).

All **activities** in the subsector of **seaport infrastructure** are **dependent**, in terms of their type, design and situation, on:

- the local water and land conditions such as location, topography, soil composition etc.;
- the type and volume of the goods being transferred (general cargo: conventional, containers, ro-ro; bulk cargo: bulk general cargo, bulk goods such as ores, coal, wheat, industrial salts or liquid or gaseous bulk goods such as oil, LNG etc.);
- the land vehicles and vessels used to carry the above;
- the resulting operational requirements and designs;
- the rail, road, inland waterway and pipeline links to the hinterland;
- the surrounding structures which already exist or which are being established (industry, commerce).

The "**seaport superstructure**" subsector includes all **non-permanent operational land-side and water-side facilities** of a seaport which are associated with its primary or secondary functions. These include, among others:

- dredgers and other maintenance and repair equipment,
- mobile supply and disposal systems, as well as fire and disaster protection

equipment (such as vehicles for dealing with oil spillages).

Non-permanent superstructure facilities in area surrounding the harbour or associated with its secondary function can be summarised as follows:

- supply and disposal superstructure
- transport and traffic structures
- maintenance and repair superstructure of harbour-related industrial and commercial establishments.

(Note: These are not necessarily linked to the harbour superstructure).

New structures, extensions, or conversions of seaports can be **summarised** in terms of their environmental effects. As far as the **environmental impacts** of special **seaports or of any harbour-related industrial activities** are concerned, reference should be made to the relevant **environmental briefs**.

It is also necessary to **distinguish between general-purpose harbours and special harbours** used only for **handling particular types of goods.** Even in "general-purpose harbours", there is an increasing tendency for goods of only one type or category to be handled in specialised facilities referred to as **terminals** (oil terminals, ore or grain terminals, ro-ro terminals etc.). This is done either for safety reasons or because of the availability of **specialist equipment.**

Furthermore, **seaports** are either **natural** or **artificial harbours.**

Natural harbours Artificial harbours

Harbours on rivers or estuaries; Artificial harbour basins and approaches;
Side harbours; Artificial islands
Harbours in bays or fjords;
Island harbours

Natural harbours generally involve **less disturbance** of the natural environment.

2. Environmental impacts and protective measures

2.1 Overview

The **environmental impacts** of sea harbours are usually **considerable** and arise on the one hand from the **construction, conversion** or **extension of seaport installations** (infrastructure as well as superstructure), but also to a large extent from the **operation of all harbour installations** and from the **industrial and commercial installations and transport systems** (both on water and on land).

The **environmental impacts** affect **water, soil and air**, all types of **flora and fauna** (both aquatic and terrestrial) and **humans.**

Causes Effects on

New construction Water
Conversion Soil
Development/expansion Air
Operation of all installations and systems Flora/fauna (aquatic/terrestrial)

Humans

In principle, **the larger the construction or expansion projects** and the **more intensive the port's handling activities** (measured in t/a), the greater the environmental impact.

Special impacts are caused by **dangerous goods,** as defined by the IMDG Code (International Maritime Dangerous Goods Code), **even in small quantities.**

The **environmental impacts** can be divided into effects in the "**infrastructural and superstructural**" sector:

- primarily caused by the harbour installation as the sum total of all the water-side and land-side structures used in shipping and the transfer of goods and
- secondarily caused by industrial installations which may be closely linked to seaports, as infrastructural facilities for the processing or refining of goods and raw materials; erecting such facilities causes changes in the natural peripheral conditions and must therefore be regarded as incursions into the natural environment and landscape.

and in the "**operational**" sector:

- primarily caused by all activities such as shipping, loading, discharging, storage, transport, supply and disposal, maintenance and repair and

- secondarily by all processing and refining activities in the industrial installations which may be associated with the port.

These **activities** bring about **changes in the natural peripheral conditions** and **habitats** and, as a result, may **affect humans, animals, nature and the landscape.**

2.2 Construction or expansion of seaport infrastructure or superstructure

2.2.1 Land-side facilities

A **harbour installation** generally requires **large areas of land**, particularly where storage areas, warehouses and perhaps industrial facilities are required. This being so, a harbour installation always has a **major impact** on the natural landscape, since **beaches, coastal rocks,** expanses of **reeds** or **mangroves** and other shoreline areas are **artificially stabilised and built over** and **the surfaces flattened and sealed.** Effects and changes occur particularly in **sensitive areas** such as **forests, wetlands and areas of agricultural use**, and also in **residential areas,** due to **soil excavation, soil replacement or backfilling, surface sealing, water drainage** and high **ground loads.** Although these are clearly unavoidable given the intended use of the installation, proper infrastructural planning will nevertheless ensure a degree of

environmental protection on the land side.

Transfer, storage and deposit areas should be created according to the **following principles**, bearing in mind the nature and volume of the goods being handled and the operating methods:

a) In the case of **ores, coal and salts**, care should be taken to ensure that

- storage areas are designed to be strong enough and dense enough to cope with the apparent density and dumping height of the material, so as to avoid any changes in the subsoil and surroundings;
- a water drainage system is planned in and around these locations adequate to deal with the rainfall occurring, to avoid penetration, seepage and draining of contaminated surface water and heavy metals into the soil and sea (settling tanks and clarification plants may be necessary).

b) In the case of **bulk goods storage**, dust formation can be effectively prevented by hall structures or sprinkling systems, though these are expensive to construct and maintain.

- Bulk goods which are sensitive to weather must in any event be stored under cover or in silos.

c) In the case of **handling operations involving oil and other liquids**, ground surfaces must be adequately sealed in the discharge and loading area and in the tank area, with a system of oil separators or other wastewater purification systems; otherwise, procedural measures are the only precautions that can be taken against contamination of groundwater and seawater due to spillages.

Land-side harbour expansions must be **planned well in advance** so that the requisite **areas** and any land to be provided by way of compensation can be **earmarked** and **kept available** by means of appropriate land-use and construction planning. This is the only way of preventing the all too common phenomenon of **harbour areas penetrating into established areas of habitation** or into **areas worthy of protection**, involving forced resettlement or land clearance, or **the uncontrolled spread of human habitation.**

Buildings, functional structures and **industrial and residential developments** are all part and parcel of the **development of a harbour zone.** The factors which contribute to a **more environment-friendly and environment-oriented planning concept** are:

- the separation of areas with different purposes;
- the use of environment-friendly building materials;
- optimisation of maximum construction/utilisation heights in relation to land area demand;
- economical land-use;
- architectural matching of buildings and functional structures to the building style of the country in question;
- landscaping through planting/greening of open spaces in the vicinity of buildings and, if possible, at the edges of the storage areas of the port;
- the use of environment-friendly technologies in industrial installations and in their operation in the harbour area;
- infrastructural measures in the field of water supply and sewage disposal, so as to safeguard groundwater and surface water stocks and maintain seawater purity.

The **development of a harbour** often involves the erecting of **industrial installations.** Experience shows that the newly created **jobs**, and often the mere hope of jobs, lead to an increased and sometimes uncontrolled **influx of workers** and their families. When **planning a harbour,** care must therefore be taken to **create conditions fit for human habitation** in terms of housing and sanitation provision. There is a particular **risk** of

ghettos developing in the vicinity of ports.

The **development of a harbour area** together with associated **industrial establishments** places an **enormous burden on all supply and disposal facilities**. **Water demand** and **sewage generation** are particularly important in terms of the environmental effects. However, the **consequences for the air and soil, land consumption and the effects of traffic**, including questions of safety, must also be taken into account as early as the planning phase.

2.2.2 Water-side facilities

Water-side harbour installations generally require **large areas of land** and therefore have a **major impact** on the natural environment and landscape. **The environmental impacts** can however be limited by **careful planning.** Therefore **when planning and laying out** the water-side structures of a seaport, one should aim to gain as much information as possible on the **prevailing environmental conditions** such as

- wind and wave conditions
- current and sedimentation conditions
- water, soil and air conditions,

on the basis of extensive prior bathymetric and hydrological measurements, natural data surveys and, if possible, model experiments, working **with rather than against these conditions.**

In addition, efforts should be made to blend the **harbour installations** into the **general landscape** as far as possible.

Silting means that regular **maintenance dredging is required, to ensure that proper depth conditions are maintained; flushing or dumping** of the dredged material causes major environmental problems, in particular because:

- the sludge may be contaminated by general water pollution, sewage discharge, oil or heavy metals;
- over long periods of time large flushing and dumping grounds are needed which are difficult and expensive to recultivate;
- dumping causes changes in the underwater configuration and the aquatic flora and fauna.

These consequences are best avoided by the early planning of **structures in harmony with the water currents** and the **provision of suitable disposal facilities** as far away as possible from areas of habitation. The same applies to the operational **disposal** of **sewage, wastewater and refuse** produced in the harbour.

The **design of harbour facilities** should take advantage of the **natural effects of the tide and currents** in the mouth or delta area of an estuary. This may serve, for example, to keep approaches clear by the careful location of **training dykes** to guide and concentrate the flow (flushing effect), of **harbour defences** (particularly in the access area, with a view to avoiding lee erosion) and of **quay installations**, which if possible should not be located in areas of dead water. **Harbour installations should not be built in brackish water areas** (where salt water and fresh water converge, leading to greater silting).

Fishing grounds and aquacultures of coastal and river fisheries, as well as other natural flora and fauna, may be adversely affected by **harbour construction**, because **large areas of water**, as well as **breeding grounds and habitats, will be lost.** Another danger posed by a harbour installation is the **damage that may result** from sewage outfalls or changes to the groundwater level in the harbour area.

Damage to fish stocks may pose a **health hazard to consumers of fish** and lead to job losses in the fishing industry.

Measures to reduce water pollution in the harbour area basically involve minimising discharges into the water or permitting only the **discharge of treated wastewater and sewage.**

In addition, ample provision should be made for the fishing industry, as early as the planning phase of the harbour facilities.

There is unlikely to be **any adverse environmental impact** from the **building materials** used to erect installations in the water (concrete, rubble); **steel piling walls**, on the other hand, are prone to severe **corrosion** in hot regions, particularly under the influence of salt and brackish water, so that they may only be used if **anti-corrosion measures** are applied. To avoid contamination, only **toxin-free paints** may be used for this purpose. **Wood** is only of **limited suitability** as a building material (in view of the short service life due to rotting in mixed water areas). **On no account should certain tropical rainforest timbers be used** (such as Bongossi woods), though these are prized as a building material because of their strength and long service life.

2.3 Port operations

The term **port operation** in this environmental brief covers not only "traditional" harbour operation (i.e. the handling and transfer of goods), but **all operational activities** which are carried out on the basis of the existing infrastructure of a seaport (including any industrial establishments) in the service, industrial, commercial and transport/traffic sectors, **on both the land and watersides.**

2.3.1 Land-side port operations

The possible **environmental impacts** of land-side port operation and the associated hazards are determined essentially by the **nature of the goods and materials** being handled. The **handling method** is also a decisive factor.

The following **environmental effects,** subdivided by the cargo types

- liquid bulk goods
- solid bulk goods
- general cargo
- containers

are possible:

(a) **In the transfer of oils, liquid chemicals or other liquids,** seawater and groundwater may be contaminated; **fire** and **explosion** may occur, resulting in smoke and gas formation;

unintentional **release or discharge** of oil, petroleum derivates, liquid chemicals or other liquids may occur;

petroleum derivates such as petrol, oil and kerosene may be accidentally **mixed**, e.g. due to wrong coupling connections or the use of the wrong pipelines or during pigging (the cleaning of a pipeline by means of a "pig") with raising of the flash point;

people - unaware of the danger - may **smoke** or **cook** in the **immediate vicinity of tank installations** or unloading terminals;

tanks may be emptied on board ships or on land, causing **dangerous gases** to develop.

Measures to **prevent environmental damage** in the liquid bulk goods sector therefore require not only **adequate infrastructural measures in the loading, unloading and tank storage areas**, but also an **efficient operational organisation** with clearly demarcated areas of responsibility and authority. Furthermore, **intensive training of the personnel** engaged in this sector is required (see **MARPOL Convention**).

From the technical and operational aspects, the following **safety precautions and resources** are needed:

- skimming equipment (oil booms, oil skimmers)
- oil-binding substances (for small quantities only)
- stocks of sand
- fire-fighting systems with hydrants
- sprinkler systems
- foam generation systems
- emergency power supplies
- individual water supply pumps
- safety containers in the tank storage area
- safe distances between tanks and other installations.

For projects envisaging the use of **oil transfer terminals, tank farms or refineries,** the personnel to be deployed must **receive training courses in good time**, in the interests of environment-oriented planning.

(b) In the bulk transfer of grains and fodders, ores, coal and industrial salts, environmental effects such as groundwater and seawater contamination, serious dust formation and noise are likely. Bulk goods conveying systems are prone to dust explosions and fire and also, because of their size, have a major impact on the natural landscape.

Besides adequate physical infrastructural measures, good management and staff training are also vital to environmental protection. It is also essential that only the designated storage areas which have been sealed in the interest of groundwater protection are used for storage and that maintenance and repair work is carried out regularly (e.g. clearing the rainwater drainage inlets in the storage areas). Dust formation and noise can in most cases only be prevented by expensive overhead cover and dedusting and sprinkler systems, and by erecting halls. Loading and transfer should be enclosed if possible, and the "free fall" of dust-forming goods should be avoided. Dust, depending on its composition and fineness, can cause chemical, biological, mechanical, electrical or electrostatic problems.

(c) In the case of **general cargo and container handling**, the **large-scale equipment** used (e.g. container bridges up to 70 m high with the water-side beam arms folded up) is a **source of noise and danger.**

This type of equipment operates rapidly and precisely and **alternatives** using ships' tackle or mobile land equipment (e.g. straddle carriers, large fork-lifts) will lead to substantial **reductions in speed and safety**.

To avoid frequent intermediate movements, **containers** are stacked on top of one another by means of special handling and stacking machinery. This is usually a necessary measure and **requires large areas of land.**

The **handling and stacking machinery**, depending on its manoeuvrability, also requires additional **space within which to move**, and generates **noise**. **Yet more space** is needed for **arriving, departing and connecting traffic.** These areas, whose surfaces are normally **sealed**, require an **efficient water drainage system** with separate **water treatment facilities.**

The **mechanisation** of the general cargo sector moreover has **socio-economic effects** on the people working in the harbour; in this context, **education and training** should be taken into account as early as at the planning stage.

Mechanised handling also produces high levels of **exhaust gas and noise** - except in the case of electrically driven equipment. **Equipment fitted with silencers and exhaust gas regulators** are to be preferred. Exhaust gas emissions and noise should be minimised by regular **maintenance**; the environmental brief Workshops deals with the relevant environmental aspects.

Containerised, unitised and conventional general cargoes may furthermore contain **dangerous solids or liquids** (chemicals etc.), which may cause **catastrophic environmental damage in the event of inappropriate handling or damage to the containers**.

Here too, the risks should be minimised as far as possible through **intensive training** of personnel, **provision of suitable equipment and correct handling/storage** of the goods in question.

(d) **Conventional general cargo** may be directly or indirectly harmed by **improper handling or storage,** depending on the nature of the goods. Goods may be easily damaged depending on the packing, or they may be damaged in storage if they are not properly protected against the weather. **Damaged or incorrectly stored goods**, which are usually worthless to the consignee, must be **disposed of.** Risks of inexpert disposal can only be avoided if the **personnel are adequately trained** and an appropriate **disposal infrastructure** is provided.

(e) **Fish and seafood** present an **environmental hazard** if improperly processed, stored and treated, through the waste matter and wastewater produced. The consumption of improperly treated fish or seafood can cause **illness.**

Therefore special care must be taken when **handling goods which are liable to deteriorate** (e.g. by continuous refrigeration and rapid handling).

(f) The environmental impacts caused by **industrial and commercial establishments in the harbour zone** and the associated environmental protection measures depend on the types of raw materials and goods being processed or refined. The **appropriate environmental brief** should be referred to in this regard.

2.3.2 Water-side port operations

This sector is characterised by **shipping activities** and the associated **operational measures**, such as:

- guaranteeing ease of shipping movements (particularly the maintaining of appropriate water depths and consequent dredging activities);
- supplies to ships and waste disposal;

- ship-to-ship transfers;
- pilotage and the control of navigation.

Since all these activities which are needed to maintain harbour operations on the waterside are carried out from ships or floating equipment, **adverse environmental effects on the water** and the sea and consequently on the **fauna, flora and groundwater** will result in particular from:

- berthing and departure manoeuvres (risk of accident leading to spillages from ships)
- refuelling (and deliveries of other supplies)
- discharging, loading and lighterage
- disposal (sewage, wastewater and refuse)
- cleaning of tanks and holds
- repairs.

The only way to combat these environmental impacts is to **train** employees in these areas and provide appropriate **equipment** in the form of tugs, supply ships, lighters, pumps, oil barriers etc. This should be instigated primarily by the **port authority or harbour operating company**. (Problems of disposal and disposal facilities are dealt with in the environmental briefs Shipping, Solid Waste Disposal and Disposal of Hazardous Waste).

A further source of adverse environmental impact is **maintenance dredging** of harbours and approaches; in this regard, refer to section 2.2.2.

The above-mentioned **environmental hazards** can only be countered by **responsible behaviour** on the part of **ships' masters** or by **close monitoring of shipping** (with the threat of penalties); **accidents** in shipping lanes and the **drastic environmental damage** which may ensue can be avoided by using the simplest possible **shipping control system** (VTMS = Vessel Traffic Management System), adapted to local conditions, in conjunction with a well-trained and organised **pilotage system**. This should be provided for as early as the planning phase.

All the **effects** of the new building or restructuring of a seaport on the local population - including the female population - should be analysed at an early stage by a **socio-economic and socio-cultural survey**, whose results should be taken into account in the planning or in accompanying measures.

3. Notes on the analysis and evaluation of environmental impacts

The assessment and evaluation of environmental hazards in this sector relies on the availability of **accurate planning documents** concerning the types and quantities of the goods being handled and **reliable forecasts** for future development. It is also necessary to determine the potential for further processing and onward transportation of goods, and also make a careful **assessment of local conditions** (terrain, soil, climate, groundwater, existing infrastructure etc.).

It is suggested that **integrated operational and construction plans** be drawn up and that **international or comparable German standards** be applied for the appraisal of the physical installations and operations, to rule out the adverse environmental consequences of an unsatisfactory assessment.

The following should apply to **installations:**

- international standards under the MARPOL Convention;
- strength, stability and service-life criteria, e.g. according to German DIN standarads or the redommendations of the German working committee on bank revetments *EAU*;

- disposal methods (sewage/wastewater/refuse) according to international standards and comparable discharge values, depending on wastewater types;
- methods of maintaining air purity, e.g. according to TA-Luft (Germany's Technical Instructions on Air Quality Control).

For **port planning**, a **detailed locational analysis** is required, primarily comprising:

- measurement of currents and oceanographic data;
- physical and mathematical model experiments to determine the optimum flow design and to prevent sedimentation;
- transport and traffic analyses.

Special attention must be paid to **guaranteeing** and **adhering to limit values**. To achieve this, the **port operating authority** must receive **appropriate training** and be made **aware of the problems.** Moreover suitable **inspection, monitoring and emergency equipment** must be provided.

Environmental impacts can only be **minimised** through a suitable **combination of installations**, built to European standards and expertly used and monitored, enabling low discharge and emission values to be adhered to.

4. Interaction with other sectors

Seaports and their approaches involve making **substantial changes** to the existing **natural, socio-economic and socio-cultural structures** of the region.

In this context, the **planning phase** is of paramount importance, during which the many possible **effects must be identified at an early stage.** What is required, therefore, is **regional planning, transport and traffic planning,** socio-economic planning and also **water framework management and overall energy planning.**

Table 1 - **Environmental effects of adjacent project areas**

Interacting project areas	Nature of intensification of impact	Environmental briefs
		Petroleum and Natural Gas

Storage and transport of dangerous goods	* Risk to water resources * Health hazard to personnel and population	Gas Disposal of Hazardous Waste Health Care Trade and Industry briefs
(where affected) Decent living conditions for larger population attracted by the development	* Sharp rise in housing demand * Demand for utilities and disposal services (water, power, waste disposal) * Public Facilities (hospitals, schools)	Provision of Housing Public Facilities Water Framework Planning Water Supply Solid Waste Disposal Wastewater Disposal

Transport integration and development	* Heavy burden on existing traffic and transport facilities (inland waterways, railways, roads) * Increased expansion of transport facilities, with consequent effects	All briefs in the transport sector
Incorporation into region's industrial development	* Development of processing industries, with consequent effects on e.g. utilities, disposal services, land-use, re-structuring of social conditions	Planning of Locations, Overall Energy Planning, Water Framwork Planning. Trade and Industry briefs (where particular sectors are affected)

5. Summary assessment of environmental relevance

Generally speaking, environmental effects are unavoidable. Nevertheless, projects in the ports and harbours sector can be planned and executed in a largely environmentally acceptable way if:

- **the goals and the elements of the project are clearly defined;**
- **the operational and physical aspects are planned in an integrated manner;**
- **the environmental conditions prevailing in the immediate and wider planning area have been thoroughly and adequately researched;**
- **all conceivable interactions and conflicts of use are taken into account from the outset;**
- **high standards are applied from the very start, but using the simplest possible designs and methods tailored to local needs, to create installations which will enable environment-friendly operation when completed.**

To ensure that the completed harbour installation will, in so far as technically possible, be operated with the minimal environmental burden, it is necessary in

the planning phase:

- to take full account of operational needs from the very start;
- to provide for the comprehensive training of the later operating personnel, based on the need to raise their awareness of environmental impacts and environmental damage, and to make provision for the continuing training and further training of harbour personnel.

Affected population groups, and women in particular, should be involved in the planning and decision-making process from an early stage, in order to take account of their interests and help alleviate environmental problems (competing land-use, environmental burden of increased traffic on housing areas etc.).

Only through such a combination of environment-oriented planning and execution with later environmentally acceptable operation of the works, can a lasting contribution be made towards improving economic conditions.

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Shipping

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1. Scope

This brief deals exclusively with ocean-going ships, including special-purpose vessels, but not to self-propelled or towed marine platforms and equipment. The transport routes are the open sea, sea lanes, shipping lanes, inland waterways, and harbours. Submarine vessels and special diving equipment for technical marine tasks of inspection, exploration and similar purposes are not included, nor are warships considered.

Ships transport an extremely wide variety of cargoes, from human beings, to solid objects, to liquids and gases. Ships are also used for special purposes in ocean dumping or incineration of waste.

Because shipping is an international activity, national specifications and regulations relating to loading and safety at sea are largely based on international agreements and conventions.

Most ships are propelled by diesel engines and are fitted with diesel power generators. There are also turbine ships with oil-fired boilers, and a few coal-fired ships still exist. There is also a series of ships with gas turbines.

2. Environmental impacts and protective measures

Environmental impacts occur even if the ship is operated correctly. Accidents and human and technical errors can damage the environment to a degree that is difficult to assess. These impacts vary from case to case and should be determined in the individual case by means of a risk analysis.

Generally speaking, protective measures nearly always include

- structural
- training or
- legal and administrative measures with internationally recognised standards providing a reference for all individual measures.

One internationally recognised specification for construction standards is the set of classification regulations of the individual classification societies, some of which have been incorporated into the safety regulations enshrined in national legislation. In addition, certain fields are governed by the "International Convention for the Safety of Life at Sea (SOLAS)" and the "International Convention for the Prevention of Pollution from Ships (MARPOL)". A

construction standard corresponding to the generally recognised state of the art is met when a ship is granted the appropriate class mark for its type and area of operation.

It should generally be borne in mind that any safety installation is to be deemed ineffective if adequately qualified personnel are not available.

The minimum international standard for the competence of a ship's crew is governed by the "International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)". On the other hand, the actual content and duration of training vary from one country to another.

To determine the environmental impacts and protective measures of the complex system known as a "ship" it is necessary to consider a network of factors relating to the spheres of marine engineering, crewing and on-shore measures (such as technical infrastructure, suitable personnel, legal requirements etc.).

2.1 Workplace and health

Direct effects on human beings are inflicted primarily by the noise of main and

auxiliary engines and machinery, and also by gaseous or other pollutant-emitting cargoes which may have an adverse effect on human health. Contamination of drinking water and foodstuffs (fish, birds) is caused by oil residues and the remains of toxic cargoes. As a rule, the former affects only crew members and passengers, although pollutant-emitting cargoes can indirectly affect third parties as well (see also 2.3 Air).

Noise-abatement measures are described in classification regulations and (in Germany) in the accident prevention regulations of the maritime employers' liability insurance association *Seeberufsgenossenschaft (SBG)*

The "International Maritime Organisation (IMO)" has issued recommendations for maximum noise levels in its resolution on "Noise Levels on Board Ships" (see Table I).

***Table 1 -* Noise-abatement measures in European maritime nations**

Noise regulations	**Fed.Rep. Germany**	**IMO Resolution A.468 (II)**	**EC Guideline**	**Sweden 1973**	**Norway 1973**	**U.K. 1978**	**Netherlands 1987**

	1980	1982	1987				
Operating areas	110	110	-	100	-	110	110
Engine rooms	85	85	-	75	-	90	85
Workshops	85	-	-	70	-	75	-
Engine monitoring and supervision rooms on vessels under 4000 GRT	75	75	-	-	-	75	75
Engine monitoring and supervision rooms on vessels of 4000 GRT and above							
Accommodation	60	60	-	55	-	60	60

areas and radio room	65	65	-	65	-	65	65
Cabins and sleeping areas	65	65	-	65	-	65	65
	60	65	-	65	-	65	65
Mess rooms	70	-	-	65	-	-	-
Recreation rooms on vessels under 8000 GRT	60	60	-	-	-	60	60
	65	-	-	-	-	-	-
Recreation rooms on vessels of 8000 GRT and above	65	65	-	55	-	65	65
	70	75	-	-	-	70	75
	60	60	-	55	-	60	60
Hobby and games rooms							

Sickbay Treatment room Offices Galleys, pantries Radio room							
Bridge area Wheelhouse Bridge wings	65 70	65 70	- -	65 70	- -	65 -	65 70
Noise areas, marked Obligation to wear hearing protection	90 90	85 85	90 90	85 90	90 90	90 90	85 85

(Values in dB)

Technically speaking, noise-abatement does not present any major problems. The engine rooms are generally enclosed and therefore allow structural noise protection to be included. Airborne noise from exhaust gas outlets on deck and in the surrounding environment can be reduced by mufflers. Other noise emissions (e.g. fans, exhaust gas noise) can be reduced by the appropriate structural measures.

Protection against pollutant emissions is achieved in the first instance by loading cargoes in accordance with the proper procedures; this requires an awareness of the particular problems involved in handling special cargoes on the part of the crew and the personnel at the ports of loading and discharge. International regulations must be observed, such as those of the "International Maritime Dangerous Goods Code (IMDG-Code)" and MARPOL -also in the shipbuilding sector - as the international standards relating to protective measures.

By installing appropriate ventilation systems in the ship's accommodation areas, the intake of air impurities can be substantially reduced.

The risk to personnel (crew and third parties) posed by the accidental release of pollutants due to collision, explosion or on-board fire may in certain cases be extreme (e.g. in the case of radioactive, highly toxic or explosive cargoes).

2.2 Water

The following can and do have an environmental impact on seawater or river water:

- oil and oil sludge and mixtures containing oil,
- cargo residues,
- operational waste from the ship (domestic refuse, engine room waste),
- waste water,
- bilge water,
- paint,
- fish waste, and
- dumping and incineration discharge.

The diesel engines on ships are powered by heavy oil, marine diesel oil, or marine gas-oil. Oil sludge occurs largely due to flushing of heavy oil and, to a lesser

degree, marine diesel oil, while the problem is almost negligible in the case of marine gas-oil.

Over 90% of all ships burn heavy oil. The quality of this fuel is steadily decreasing, as it is made from crude oil residues from which as many high-quality distillates have been extracted as possible. In addition, the fuel has a high sulphur content (up to 3%). The sludge fraction in heavy oil processing on board at present amounts to about 3% of total fuel consumption.

In addition, residual oils result from oil changes on machinery and equipment.

Mixtures containing oil occur in the form of tank flushing water, bilge liquids and oily ballast water.

Under MARPOL, all liquids containing oil must, under normal operating conditions, pass into the sea only via oil separation systems, and may not do so in any circumstances in the form of sludge. The sludge and the separated oil residues are either to be incinerated on board in special furnaces or discharged in port to the oil collection facilities, though there are not enough of these available worldwide.

The most effective ways of preventing oil pollution from normal maritime operations are to ensure awareness, understanding and observance of MARPOL regulations among ships' crews, to provide adequate facilities for discharging oily residues and to carry out effective supervision and monitoring of adherence to the regulations. Machinery fuelled by marine diesel oil or marine gas-oil (both of which, incidentally, are not substantially more expensive than heavy oil) help reduce sludge to a substantial degree.

Depending on the facilities available to the individual ship for discharging oil residues at disposal facilities or incinerating them on board, it may be necessary to provide tanks for sludge and slop (flushing water containing oil). This is the case, for example, if on-shore disposal facilities in the ship's area of operations are inadequate. Recommendations are currently being prepared by the Marine Environment Protection Committee of the IMO (MEPC) for the dimensioning of such tanks.

Measures which extend beyond the international standard include, among others, the use of double-hulled vessels as tankers, doing away with pipeline systems for direct disposal, the use of detergents specifically approved by the manufacturers of the oil separation systems, economic disposal incentives and public-law

prohibitions on substandard ships.

Cargo residues occur in solid or liquid form after each discharge of non-containerised cargo (e.g. damaged cargo, non-pumpable residues). The disposal of solid and liquid waste and residues is likewise governed by MARPOL.

It is advisable to avoid introducing any solid or liquid cargo residue into the water and instead to dispose of it on land. This applies both to substances which fall under MARPOL Annex III and to substances not covered by MARPOL.

With regard to chemical tankers, it should also be noted that double-hulled vessels (which should always satisfy at least the standards of IMO Type 2 ships, under the "International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC-Code)") are not only more collision-resistant, but also help reduce the volumes of residue by having smooth tank walls (in contrast to single-hulled vessels).

Since 31.12.1988, the disposal of general ship's waste has been mandatorily governed by MARPOL Annex V. The discharge of certain types of waste is however permitted in principle at distances of 12 or 25 nautical miles offshore.

One measure which goes beyond the scope of MARPOL, to prevent pollution of water by refuse, is to treat the ship as a closed system. This means that all the waste and residues generated during operations are temporarily stored and handled in such a way that no pollutants whatsoever can enter the water. This includes collection of different types of refuse in separate containers, provided appropriate disposal facilities are available on shore.

The treatment and disposal of wastewater has not yet been mandatorily regulated on an international level (except for the Baltic Sea area), because MARPOL Annex IV -regulations for the prevention of contamination by ships' wastewater - has not yet come into force. Moreover, MARPOL only covers what is referred to as foul or dirty water (sanitary sewage), while grey water (such as wastewater from galleys or washing water) may be introduced untreated, even after Annex IV comes into effect.

As in the case of ship's waste, a closed circuit is recommended, which will not allow any contaminating discharge whatsoever. Faecal matter can nowadays be processed biologically, and there are waste macerators, waste presses and grease separators for wastewater from galleys.

Paint from the ship's outer skin contains toxic anti-fouling additives. Slow dissolving can contaminate the water and effective alternatives are not yet known. The Marine Environment Protection Committee of the IMO (MEPC) is however working on a way of developing environment-friendly alternatives.

Waste from fish processing at sea is not yet subject to MARPOL standards. Rather than introducing all the waste into the sea, it is possible to use on-board fishmeal systems; if these are used, only minimal quantities of waste need be discharged into the sea.

Waste dumping and incineration ships are an obvious and deliberate menace to water purity, which can only be prevented by halting such operations.

***Figure 1* - Disposal methods**

2.3 Air

The operation of combustion engines causes the following environmentally relevant gases to be released into the atmosphere (the air): Carbon monoxide, carbon dioxide, sulphur dioxide, hydrocarbons and nitrous oxides; soot is also

emitted.

In general a distinction should be made between the following type of atmospheric emission:

- **exhaust gases from engines, auxiliary engines, main and auxiliary boilers;**
- **gases from the cargo as a result of gas leakage or evaporation (tank respiration);**
- **gases from the cargo or released during loading and unloading due to**

displacement of the tank atmosphere when the tanks are filled without a gas displacement system

removal of cargo residues due to forced ventilation of the cargo tanks

degassing of cargo tanks.

In certain cases this may be rectified by cleaning of exhaust gases. Merely ensuring correct adjustment and maintenance of engines and boilers will limit

emissions.

The energy consumption is that of the average ship of the class in question. In the case of ocean-going vessels, two figures are quoted because of the differing sulphur contents of the fuels used. It is assumed that heavy oil contains about 3% sulphur and marine diesel oil about 1%.

There are no international agreements or recommendations regarding emission limits for ships or regulations regarding the minimum fuel qualities (and thus e.g. the sulphur content). The MEPC is however working on this problem too, so as to be able to develop recommendations for international standards.

The measures specified in MARPOL Annex II (see above) are used to avoid emissions from cargo tanks on chemical tankers.

With volatile gases, appropriate measures include mechanical precautions to ensure the containment of the gases which escape during loading and discharge operations, even where these are allowed to escape under MARPOL specifications. This is particularly important in the case of substances hazardous to the global atmosphere, such as halogen compounds.

Cargoes of gas tankers which are liable to cause emissions or explosions are only subject to MARPOL II if they have a vapour pressure of max. 2.8 kp/cm^2 at a temperature of 37.8 degrees Celsius.

There are no international regulations governing the discharge of gases; there is however a "Code for Construction and Equipment of Ships Carrying Liquified Gases in Bulk (1983)", issued by the IMO.

On gas tankers, the evaporating gases are recondensed or incinerated wherever possible.

Incineration ships which burn chlorinated hydrocarbons are responsible for large emissions. The hydrogen chloride and certain other substances are absorbed by the sea, but dioxins and furans are also produced, and may have an adverse effect on ecosystems and water quality. Nearby coastal areas may be polluted if the winds are in the appropriate direction. No effective preventive measures are known, therefore this disposal method is not recommended.

2.4 Seabed

Ocean dumping and waste disposal has a direct environmental impact on the seabed, and an indirect effect as a result of contamination of the water with substances of higher specific gravity than seawater. Mechanical impairment may occur due to the dredging of harbours and shipping channels and, to a very small extent, due to the suction and swell effect of moving vessels.

The disposal of refuse into the sea should be banned entirely (see above).

Mechanical impairment can be reduced by restricting the draughts and speeds of shipping to a minimum.

2.5 Ecosystems

The ecosystems of the sea and rivers can suffer lasting damage due in particular to the introduction of foreign and toxic substances which accumulate in the sediments or as suspensions in the water, and pass into the food chain.

As well as coating seabirds and other sea creatures, oil also causes oxygen deficiency in oil-covered sediments and draws oxygen from the water when the oil decomposes, which may inflict secondary damage on the fauna. Large, slowly-

sinking oil slicks destroy all microflora and microfauna by oxygen deprivation.

To combat sea pollution by ocean-going vessels, not only should the minimal requirements of MARPOL be taken as the basis, but also the closed-circuit system should be introduced for ships. This will prevent any substances being discharged into the sea; measures to develop and expand shipping should thus always be accompanied by appropriate on-shore infrastructural planning and installations.

3. Notes on the analysis and evaluation of environmental impacts

3.1 Water

Emissions into water are mainly the result of deliberate rule violations, accidents, technical defects or simply ignorance on the part of the crew. The long-term effects of oil and toxic chemicals from cargo components or cargo residues are a particularly serious environmental problem.

Only very limited discharge of domestic and operational waste is now permitted by law, therefore this should be eliminated altogether.

The disposal of tank flushing water, oil residues, and refuse still permitted under MARPOL regulations and the deliberate release of ventable cargo residues could be done away with if adequate receiving facilities were available, appropriate levels of training were given and requirements going beyond the scope of MARPOL were laid down, or if design improvements were introduced.

Wastewater, though not yet the subject of binding international regulations, can be treated by means of built-in treatment plants which are already available for small vessels and point the way ahead for the future.

The use of ships for the incineration and dumping of waste inflicts incalculable long-term damage on the environment (toxic effects on water and air) and must therefore be stopped.

The discharge of fishing waste into the water (high organic contamination burden) can be almost entirely eliminated by the installation of appropriate recycling systems.

3.2 Other media

Emissions from ships into the surrounding atmosphere result for the most part from exhaust gases from combustion engines and partly from emissions of chemicals and gas tankers (disregarding refuse incineration ships, dealt with under 3.1), as well as noise.

The IMO, in collaboration with the "International Standardisation Organisation (ISO)", is in the process of specifying minimum fuel qualities and formulating emission conditions.

Through design measures in conjunction with operational procedures, extending beyond the international minimum standards such as MARPOL and classification specifications, a substantial reduction in cargo emissions can be achieved, with a view to attaining a cargo yield of 100 % (i.e. without any undischargeable residues remaining on board).

3.3 Special features

Particularly serious environmental damage is caused by accidents. The

environmental risk from accidents varies depending on the type of ship, its size, the nature of the cargo and the waters through which it passes. It is accordingly recommended that a risk study be carried out in the individual case, based on the special conditions which prevail, to determine the potential environmental impact.

Special attention must be paid to the transport of special cargoes:

- **hazardous cargoes according to the IMDG Code,**
- **hazardous liquid bulk cargoes,**
- **crude oil and its derivatives etc.**

4. Interaction with other sectors

There is direct contact with the sector of shipping administration and the sector of ports and waterways (see also the environmental brief Ports and Harbours, Navigable Waterways).

4.1 Shipping administration

Efficient ship operation, complying with all environmentally relevant design requirements and organisational measures, depends on an existing body of shipping legislation, an effective system to administer that legislation and a functioning judiciary.

Complex industries like the shipping industry can only be regulated through legislative measures introduced in a wide variety of sectors, so as to minimise environmental impacts. The following peripheral sectors may be mentioned in this regard:

- **incorporation of international construction, safety and environmental regulations and codes of conduct into national law,**
- **labour and social legislation,**
- **training regulations,**
- **administration, police and penal provisions.**

Practical implementation requires a system of administration which at least takes account of underlying needs. These include, in particular:

- **technical supervision and monitoring, of the environment as well**

- social supervision and monitoring
- nautical/technical planning and measures
- development, coordination and support of the necessary training courses, including those intended to raise awareness of environmental issues.

An appropriate legal system is also needed to implement and define the relevant legal consequences.

4.2 Ports and waterways

In the port sector, the following are particularly important in the interests of the environment:

- reliable and environment-friendly handling technology,
- suitable storage facilities,
- reliable and orderly delivery and removal of cargoes,
- provision of necessary waste disposal facilities,
- availability of appropriate emergency equipment and personnel (fire services, ambulances, port tugs, pilots, equipment to deal with oil and

chemical accidents etc.).

To protect against accidents, navigational aids and navigation marks are required for all navigable waters of the port, shipping lanes, coastal waters and the open sea immediately outside the port.

In addition, care must be taken to ensure that minimum water depths are known and any other necessary precautionary measures are taken in coastal and open waters (speed restrictions, coastal defences, closure of protected areas etc.).

5. Summary assessment of environmental relevance

Ships can cause environmental damage particularly as a result of

- **crude oil and its derivatives and combustion gases,**
- **hazardous solid and liquid cargoes and cargo residues,**
- **operational waste,**
- **wastewater,**

- shedding of toxic paints.

For the most part, pollutants are only released into the atmosphere or water as a result of deliberate rule violations, ignorance or accident or because design specifications and/or operational procedures are not internationally binding.

If ships are designed as closed systems, with appropriate disposal facilities being provided in destination ports, both discharges and emissions can be substantially reduced.

Technical standards for ships should always take account of new developments.

Environmental damage caused by ships can be reduced to a minimum if technological and design specifications are adhered to, but also and in particular if the appropriate on-shore administrative and technical infrastructure can be guaranteed.

The impact of shipping accidents must be assessed on a case-to-case basis by means of a risk analysis specially prepared for the case in question.

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27. Plant production

Contents

1. Scope

The following terms recur frequently in this environmental brief and therefore require definition:

- Single cropping involves growing only one crop on a particular area of land, e.g. rice. The sequence in which various single crops are grown one after the other in a field is known as the crop rotation.
- Intercropping is a system in which a number of different crops grow together for the entire vegetation period or part of it, e.g. a combination of cassava, cowpeas and millet.
- Annual crops are generally herbaceous plants with a one-year

vegetation cycle (e.g. cereals, legumes, various vegetables, tobacco).
- Perennial crops are plants which are used over a number of years; each plant is sowed or planted only once, e.g. fruit trees, tea, coffee and cocoa.
- Monoculture involves growing a particular crop on the same area of land over a number of cultivation periods, e.g. sugar cane.

Taking into account the production of wood, self-regenerating raw materials, animal fodder and crops used in the manufacture of semi-luxury goods, plant production represents - in terms of area - man's major form of interference with the Earth's natural balance.

Traditional farming systems are usually based on intercropping and tend to be subsistence-oriented. External inputs such as fertilisers and pesticides are uncommon and are used on only a small scale.

By contrast, large-scale plantation farming generally takes the form of monoculture (sugar cane, cotton) or permanent cropping (coffee, tea, cocoa). These forms of cultivation are market-oriented and dependent on external inputs.

Plant production involves activities in areas such as

- **plant protection**
- **agricultural engineering and animal traction**
- **irrigation**
- **species and variety selection**
- **tillage and fertilising**
- **crop tending and weed control, harvesting, post-harvest treatment, storage**
- **erosion protection and control.**

Crops are grown to meet the needs of the producer or the market. They also play a role in protecting soil, air and water.

Plant production is carried out on farms, for the most part using family labour, in order to ensure subsistence and earn monetary income.

2. Environmental impacts and protective measures

In agroecosystems, man becomes the dominant element in the ecosystem (anthropogenically oriented ecosystems). Agroecosystems differ in particular from natural ecosystems in that natural regulation processes take second place to control by man.

In the natural environment, plants form part of the ecosystem and play a key role in preserving it. Depending on the cropping method used, the nature, intensity and interaction of cultivation measures give rise to specific environmental impacts. These may cause a reduction in the diversity of species, disruption of the soil structure and pollution of the soil, water and air (pesticides, salts resulting from irrigation and fertilisation, nitrate etc.) Natural ecosystems with their wide variety of functions are replaced by artificial land-use systems poor in species.

Growing use of industrially produced inputs (fertilisers, pesticides, machines, energy) and inappropriate cultivation techniques lead to contamination of drinking water by fertilisers and pesticides, as well as causing soil erosion, desertification and genetic erosion.

2.1 <u>Environmental impacts</u>

2.1.1 Soil

Soil forms the basis for plant production and thus performs a vital function in guaranteeing human survival.

Soil conservation is essential if man's living environment is to be maintained in a healthy state and a sustained supply of high-quality foods is to be ensured.

Opportunities for changing the conditions prevailing on a particular site are limited. Cultivation measures must therefore be geared to the natural conditions under which the land is used.

Erosion - in other words the removal of soil by water and wind - is one of the most problematic consequences of agriculture, particularly in the tropics.

The actual extent of erosion depends on the type of crop and form of cropping. To minimise erosion, efforts should be made to ensure that there is ground cover all year round. In the case of monoculture and single cropping, the risk of erosion becomes greater the more slowly the young plants develop (e.g. maize, grain legumes), the lower the planting density is and the more comprehensive the

weed control measures are. As annual crops such as cereals, tubers and grain legumes entail frequent tillage, they have an adverse effect on the soil structure and are thus conducive to erosion.

Perennial crops such as fruit trees generally prevent soil erosion once the stand is complete; they provide permanent shade, which has a positive effect on the soil structure.

A soil's erodibility depends among other things on its physical properties. Fine sand and abraded particles can be displaced most easily, whereas a high stone and clay content inhibits erosion. A high humus content stabilises the soil structure and increases the water storage capacity; both of these factors inhibit erosion.

The most important ways of controlling erosion are:

- **adequate ground cover (intercropping, underseeding etc.);**
- **"storeyed" cultivation through integration of trees and shrubs;**
- **division of cropping areas into small units and creation of windbreaks at right angles to the direction of the prevailing wind;**

- avoidance of overstocking and measures to prevent animals from grazing on newly sown areas (see environmental brief Livestock Farming).

Excessive mechanisation of tillage and harvesting can lead to compaction, plough sole formation and puddling, particularly in the case of tropical soils with a weak structure. This may have the adverse effect of reducing water infiltration and the air supply for the soil flora and fauna as well as for the crops. Mechanisation can also lead to changes in the division of labour between men and women.

Although frequent tillage generally has a stimulating effect on microbial activity and thus also on replenishment of the nutrient supply, it has disadvantages in the tropics:

- humus decomposition is excessively rapid on account of the high temperatures,
- the soil fauna are adversely affected and formation of new humus is thereby delayed.

Single cropping promotes the spread of pests on a large scale and tends to

necessitate substantial use of pesticides. Introduction of pesticides into the soil has adverse effects on the soil fauna and flora.

Organic matter plays a major role in the dynamics of tropical soils. It stores water, provides a living environment for soil organisms, promotes structural stability, and both supplies and stores nutrients. It is above all in storing nutrients that organic matter performs an especially vital function, as tropical soils seldom contain high-quality nutrient-fixing clay minerals. Use of mineral fertilisers therefore depends on the proportion of organic matter in the soil. If the amount of fertiliser used is not in correct proportion to the organic matter, there is a danger of leaching and of the fertiliser passing into deeper soil layers. Use of too much fertiliser is thus ecologically undesirable and economically disadvantageous.

The risk of unbalanced nutrient depletion is greatest in the case of monoculture and single cropping, e.g. in the case of maize, cocoa, root crops and tubers. Where a number of plant species are grown in an intercropping or crop rotation system this risk becomes smaller, as differing nutrient requirements have to be met. As such forms of cropping incorporate plants with different root systems (shallow, deep) and nutrient requirements (high, low), competition for nutrients,

water and light is substantially reduced.

2.1.2 Water

The erosion referred to above can lead to eutrophication of bodies of water through the introduction of nutrients, e.g. liquid manure and nitrate, and to contamination with toxic pesticide residues.

2.1.3 Air

The climate in multi-storeyed stands growing in an intercropping system is better i.e. more balanced, than that in stands of annual crops forming a monoculture or single cropping system. The wind velocity is lower and thus better for crops susceptible to the wind (e.g. bananas).

Air pollution caused as a result of plant production stems primarily from chemical plant protection measures. Evaporation of ammonia during application of solid or liquid manure has hitherto been of only minor significance. Under tropical conditions (high temperatures, low soil sorption capacity), up to 80% of the total nitrogen may evaporate.

Pollution of the air and atmosphere is caused by waste gases resulting from use of machinery, slash-and-burn techniques and burning-off of crop residues, as well as by discharge of gases such as methane and nitrous oxide by swamp rice and large herds of cattle. These factors play a part in the greenhouse effect.

2.1.4 Biosphere

The risk of both the loss of species and a change in the balance of species increases in proportion to the intensity of plant production activities. Controlled shifting cultivation - observing the necessary fallow periods - encroaches least on the natural environment in terms of area if only level areas are cleared on a selective basis. This helps not only to preserve the forests, particularly the rainforests and their resources, but also to protect forest-dwellers, who often possess know-how about things such as plants with potential pharmacological uses and the ecological interrelationships within their living environment.

Systematic cultivation of crops and the related mechanical and chemical forms of weed control cause wild plants to be largely displaced, leading to a reduction in the number of species.

In regions subject to periodic droughts, large-scale cultivation of certain woody plants in a monoculture system substantially increases the fire risk. In addition to nutrient and leaching losses, this can also result in unwanted destruction of grass and tree species not resistant to fire.

Displacement and destruction of plants leads to a reduction in biological diversity. Extensive use of rainforests also substantially reduces the variety of animal species, e.g. in the case of primates and birds.

Natural ecosystems are adversely affected not only by land being required for plant production but also by being broken up (e.g. by traffic routes), which can result in a loss of stability.

Use of land for plant production generally leads to the loss of forest, dry, wet and aquatic biotopes and causes the landscape to take on a uniform nature, e.g. as a consequence of land clearance, drainage, levelling and irrigation.

By comparison with the natural vegetation, plant production destroys habitats and reduces regional diversity. Standardisation of products for the market and breeding to obtain specific traits (e.g. yield, shape, colour) play a part in the loss

of local varieties (genetic erosion).

2.2 Protective measures

2.2.1 General conditions

Plant production is influenced to a particularly large extent by general conditions; these may relate not only to climate but also to national (e.g. land ownership situation) or international (economic relations) factors.

Many climatic and vegetation zones are highly sensitive to interference by man, whose activities generally destroy the vegetation, as in the following cases:

- clearance of the tropical rainforest in the Amazon basin for the purpose of obtaining high-grade timber
- slash-and-burn land clearance by arable farmers in Nigeria's tree-studded savannah, where the transition to permanent cultivation no longer allows the land the opportunity to regenerate
- overgrazing in the Sahel zone as a result of overstocking with large numbers of livestock which remove the already sparse vegetation.

The consequences are disastrous, not only in the humid tropics but also in places which receive less rainfall. As there are virtually no plants left to provide ground cover, the soil undergoes changes within the space of a few years; a key role is played here by the increased decomposition of organic matter in the soil and the fact that the introduction of new organic matter is reduced to a minimum.

Within the existing world economic order, the terms of trade for the countries concerned have steadily deteriorated. It is above all these countries which have been hit by the increased cost of energy and finished products. International agricultural policy likewise does nothing to ensure balanced promotion of plant production.

Rapid population growth means that farms are becoming increasingly small and the land is thus being used more and more intensively. Farms in Latin America today already have an average size of only 2.7 hectares; those in Africa on average cover 1.3 hectares, while the corresponding figure for Asia is less than one hectare. What is more, 10% of persons deriving their living from agriculture in Africa, 25% of those in the Middle East and 30% of those in Latin America own no land at all. Two thirds of those who do possess land own only a tiny area and cannot afford capital-intensive technical inputs such as pesticides, herbicides and

mineral fertilisers.

As land becomes increasingly scarce, farming systems undergo a transition from shifting cultivation to semi-permanent and eventually permanent arable farming. This process has already been largely completed in Asia, while in much of Africa and Latin America it is still under way. The changeover to permanent arable farming means that there are no longer any fallow periods (forest, bush, pasture) which allow the soil to regenerate; soil fertility declines and eventually remains at a fairly low level permitting only substantially smaller yields. The shortage of land also necessitates use of areas such as slopes at risk from erosion and thus contributes to environmental degradation.

The relative importance of the crops grown also changes. In the humid and semi-humid tropics the cultivation of yams, sorghum, and maize declines in significance, while crops such as cassava and sweet potatoes become more important. The last-mentioned crops produce relatively good yields even on poor sites, but at the same time cause the soil to become exhausted more quickly.

In many countries, both intensification of agriculture and the industrialisation process are having increasingly adverse impacts on the environment.

Waterlogging, salinisation and sedimentation cause the irrigated cropping areas - often created at considerable expense - to lose their fertility after only a few years, which gives a rise to a considerable drop in yield. Traces of persistent pesticides are being increasingly found in bodies of surface water and groundwater reservoirs. The past decade has seen a sharp rise in the number of people suffering pesticide poisoning, while at the same time there has been an enormous increase in the number of pest species resistant to the commonly used pesticides.

The factors described here are generally to be found wherever efforts are being made to raise yields through targeted, conventional modernisation of agriculture. However, such problems are not simply consequences of large-scale agricultural projects, but also arise as the cumulative result of numerous activities on the part of smallholders.

As the actual environmental costs have little or no impact from the farm management viewpoint, there is no incentive to take measures aimed at conserving natural resources or producing sustained improvements in efficiency. Land law, taxation policy and subsidisation policy, along with ascertainment of the external costs involved in production and consumption, are areas which the

state must tackle in the interest of promoting environmentally oriented plant production.

There are certain concepts, such as that of ecodevelopment, which are based on the necessary integrated approaches. Tried and tested measures such as integrated plant protection, ecofarming and others point the way towards sustainable development.

2.2.2 Ecofarming

Ecofarming aims to achieve a high sustained level of productivity on the site in question under "low external input" conditions and at the same time to preserve or recreate a balanced ecosystem.

This applies in particular in densely populated regions with smallholder-based farming structures and under economic conditions which largely preclude use of external inputs (e.g. mineral fertilisers), for in many cases such inputs are economically non-viable, unaffordable or unavailable on account of supply shortages. Intensification of agriculture must therefore be based on more productive use of scarce goods (nutrients, water, energy) and underutilised idle

resources (e.g. labour, individual initiative).

The demand for stability and sustainability stems from the obligation of each generation to pass on to future generations an environment that remains capable of guaranteeing the fundamentals of human existence. The demand for productivity coupled with stability is often seen as a conflict of objectives between irreconcilable short-term and long-term (and frequently also between microeconomic and macroeconomic) viewpoints; in most cases it is the short-term microeconomic considerations that prevail. Ecofarming must endeavour to achieve both objectives to an equal extent.

Ecofarming, or "site-appropriate agriculture" as it is also known, involves treating both regions used for agriculture and individual farms as ecological systems. However, the concept of "site" must not be restricted to natural conditions (soil, climate).

Consideration must also be given to economic development (price-cost ratios, incomes), farm-specific conditions (access to factors of production) and the internal forces influencing a farm's operations (self-sufficiency, risk minimisation, preservation of soil fertility). Last but not least, it is essential that man, together

with his culture, needs, taboos and habits, be viewed as a component of the ecological system and not as an outsider.

This integrated approach requires a certain degree of geographical differentiation. Agriculture in many countries is affected by a growing shortage of raw materials and energy and by the accompanying rise in prices. This is particularly true of countries which are in debt and possess little foreign exchange. It is thus these countries above all which must develop forms of agriculture that permit a high degree of self-sufficiency (within a self-contained system) and decentralisation (as well as self-regulation) at national and regional level and within individual farms.

The major elements of ecofarming are as follows:

- creation of appropriate vegetation

  inclusion of trees and shrubs in arable farming
  creation of erosion-protection strips parallel to the incline on slopes and planting of hedges to divide a farm into numerous small fields

afforestation on the poorest and most degraded soils

- **intercropping, alternating with intensive fallow**
- **organic manuring**
- **integrated livestock husbandry**
- **improved mechanisation**
- **supplementary use of mineral fertiliser**
- **integrated plant protection and selective weed control**

The elements listed above are given in order of precedence. As it is impossible to introduce the entire package of measures immediately, this form of classification indicates which measures must be given top priority for the purpose of preserving, increasing and stabilising soil productivity.

The following key areas of activity and options in the plant production sector should be combined with one another according to the nature of the site:

- **farm planning and organisation (information systems, economic thresholds, soil investigations, climatic data)**
- **design of cropping system (single cropping, intercropping etc.)**

- variety and seed selection (resistance, quality, quantity)
- tillage

conventional
minimum tillage
direct drilling

- cultivation and land use (crop rotation, sustainable cropping capacity)
- plant nutrition (fertilising)

organic
mineral

- plant protection

mechanical
biological
chemical

To sum up, it can be said that environmentally sound, site-appropriate

agriculture aims

- to guarantee that plant production is geared to natural conditions, i.e. site-appropriate;
- to preserve the soil structure, the biological processes taking place in the soil and the soil's fertility;
- to prevent erosion damage;
- to prevent contamination of groundwater and bodies of surface water;
- to prevent adverse impacts on biotopes adjacent to agricultural land as a result of the introduction of substances or other consequences of cultivation measures;
- to preserve typical landscape features;
- to take account of the requirements of nature conservation and protection of species, particularly as regards preservation of ecologically valuable biotopes, within the scope of overall consideration of the environment;
- to make livestock husbandry an integral component of environmentally sound agriculture.

3. Notes on the analysis and evaluation of environmental impacts

In the plant production sector, the following assessment criteria lend themselves to direct or indirect measurement:

- **changes in the biotope (diversity of species of flora and fauna)**
- **impacts on finite natural resources (minerals, ores, water, atmosphere)**
- **impacts on global ecological relationships (net energy production: energy audit comparing energy fixed by a crop plant/harvested product and energy used in its production)**
- **contamination levels (chemical products, salts, dusts, gases)**

Limits varying from one country to another have been laid down for many substances occurring in agriculture. Although many countries have maximum-quantity regulations covering immissions in water, air and soil, these are generally concerned with the effect of pollutants on human health.

As the properties and sensitivity of tropical soils vary greatly, a site survey must always be conducted before project planning commences. Such a survey involves mapping the soil types with regard to their heat, water, air and nutrient balances as well as their susceptibility to erosion. The soil type can be determined in the field or by means of granulometric analysis in a laboratory; once this has been done it is possible to assess the risk of compaction. Measurement of the infiltration rate permits more accurate appraisal of the erosion risk. Tolerance limits for humus decomposition can be formulated only on the basis of the soil conditions and the land use situation. The humus content can be roughly ascertained in the field; precise determination can be carried out in the laboratory by means of ignition loss, wet incineration or gas chromatography.

Spade analysis can be used for simple assessment of soil structure and biological activity; rooting characteristics are of particular importance. The findings can be substantiated in the laboratory by means of wet screening (aggregate stability), analysis of the C/N ratio (nitrogen availability) etc. The presence of effective root symbionts (nitrogen-fixing organisms, mycorrhiza) can be detected only by way of infection tests.

The extent of the leaching risk (particularly for nitrate and pesticides) can be

ascertained by determining the field capacity of the soil profile down to the effective rooting depth. This can be estimated in the field with the aid of a drilling stock; it is advisable to conduct a pore analysis of typical soil horizons in order to calibrate the response. However, excavation of a profile is essential in some cases, above all if waterlogging or crusting is suspected.

Deficiency or toxicity symptoms in crops may prompt determination of nutrient status or contamination level. Measurement of the pH value as a function of soil depth can often reduce the necessary scope of analysis and provides information about the lime requirement. Measurement of effective cation exchange capacity and base saturation yields pointers regarding nutrient imbalances and the degree of salinisation. In the case of trace elements and heavy metals, plant analysis is to be preferred. The results allow appropriate recommendations to be made regarding fertilising or - where necessary - rehabilitation.

A body of water can be characterised with relative ease by means of quality classification, which is carried out by determining the pH value, temperature, oxygen content and important indicator organisms. If such organisms are not present or are unknown, the water's ammonium and phosphate content can also yield information about the trophic level. Analysis of biochemical and chemical

oxygen demand (BOD, COD) allows conclusions to be drawn regarding the degree of pollution with degradable organic substances. The requirements to be fulfilled in terms of water quality will vary depending on the planned use.

It is above all in semi-arid regions that hydrogeological investigations are necessary for assessing the groundwater reserves. Such investigations can yield information on subsoil conditions and the location of the catchment areas. Current annual evaporation and groundwater recharge rate can then be estimated on the basis of the land use and soil distribution determined in the course of the site survey. If the rate at which the groundwater is tapped (drinking water, irrigation) permanently exceeds the recharge rate, lowering of the groundwater may cause severe damage to land which is in a near-natural state or has undergone reforestation. In such cases the groundwater must also fulfil more stringent quality requirements, since its use as drinking water must not be restricted.

Areas used for plant production often serve to neutralise or reduce emissions emanating from other areas. Correctly designed intensive agroecosystems can in fact sometimes perform such functions more effectively than the potential natural vegetation, because it becomes profitable, from a certain yield level

upwards, to neutralise immission-induced damage through appropriate use of inputs (e.g. liming to offset the introduction of acid). The same applies to climatic effects, which can be positively influenced if suitable land and the correct forms of cropping are selected.

Summarising assessments of energy flows and natural cycling systems, which also yield information about loading capacities, will be highly unreliable in the absence of adequate familiarity with the species involved and their interrelationships.

4. Interaction with other sectors

Plant production always has impacts on the environment, either directly or through its links with other areas. By virtue of its objectives and impacts it has particularly close links with the following areas featured in farming systems:

- **Plant protection**
- **Forestry**

- Livestock farming
- Aquaculture
- Agricultural engineering
- Irrigation

The objectives pursued in these sectors (see relevant environmental briefs) may be compatible with those of plant production, have no bearing on them or conflict with them. In the same way, impacts of plant production may be increased, reduced or offset by measures in these areas. When assessments are being carried out, attention must be paid to the possibility that impacts generated by activities in different areas could have a cumulative effect and thereby increase the amount of damage done. Such processes can be regulated with the aid of research and advisory work, backed up by instruments in fields such as legislation, poverty alleviation, self-help and advancement of women.

If plant production is on a scale extending beyond subsistence level, it also has links with agroindustry. Sinking of wells as part of schemes to provide rural water supplies can accelerate the desertification process, which has disastrous consequences for plant production.

As many countries require an increasing amount of land for settlement, transport systems, trade and industry and sometimes have to meet this need by developing areas formerly used for plant production, conflicts inevitably arise (spatial and regional planning, location planning, transport and traffic, large-scale hydraulic engineering). Although improvement of the transport system facilitates access to inputs (fertilisers, workshops) and sale of produce, land development within natural ecosystems can accelerate the destruction of such systems. The need for erosion control measures generally arises as a result of erosion caused by forms of cropping inappropriate to the site concerned. The availability of renewable energy sources and compostable domestic waste can also be of importance for plant production.

5. Summary assessment of environmental relevance

In order to prevent plant production from giving rise to unintentional developments, ascertainment of the initial situation and appraisal of potential consequences must be followed by regular assessment of forecast and actual changes in environmental conditions. The same applies to social conditions, as

there is a close interrelationship between cultural and economic factors on the one hand and the natural environment on the other hand.

The impacts of plant production generally consist in reduction of the diversity of species, adverse effects on the nutrient balance as well as on the physical and chemical properties of the soil, and contamination of the environment with pollutants.

Appropriate planning techniques and technical measures have been developed and must be taken into consideration. It is essential to refute the opinion that plant production activities (including biological erosion protection measures) have little or no impact on the environment.

Resource-depleting impacts are generally unwanted side-effects which are not directly related to the production goals. It is precisely when these side-effects are ignored that the natural environment will suffer damage and adverse long-term consequences will arise in the economic and social spheres.

Careful planning and implementation will ensure that plant production has minimal environmental impacts, has no undesirable social consequences and is

economically efficient.

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28. Plant protection

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1. Scope

Plant protection measures are carried out to limit performance and yield losses in crop production during the growing season and afterwards (storage protection) as well as for quarantine purposes. They serve primarily to safeguard yields, although in combination with other cultivation measures they can also help to raise yields.

A wide variety of individual measures - with varying ecological, economic and socio-economic impacts - are available for keeping harmful organisms (diseases, pests, weeds) below the economic threshold. To reduce the probability of damage, preventive measures are taken in the areas listed below. Some of these can be regarded as belonging to the field of plant production (cf. environmental brief Plant Production), which reflects the close links between the two sectors:

- site design (hedges, border strips etc.)
- site and variety selection
- sowing, planting
- healthy seed and planting stock
- crop rotation, intercropping
- tillage, land improvement
- fertilising
- crop tending
- harvesting
- storage

Measures in these areas are backed up by the following direct forms of plant protection:

- physical methods
- chemical methods
- biotechnical methods
- biological methods
- integrated methods

Physical methods directly destroy harmful organisms, aim to retard their development or prevent them from spreading. They can be divided into mechanical and thermal measures. The former include tillage to control weeds and pests (hoeing, removal of affected parts of plants and intermediate hosts), flooding of fields to combat soil-borne harmful organisms (e.g. Fusarium oxysporum, which causes banana wilt), laying of sticky belts to trap flightless insect pests and other measures for catching pests or keeping them away from crops, such as fences, trenches (locust control), traps and picking-off of pests. Thermal methods utilise the harmful organisms' sensitivity to high or low temperatures. They include hot-water treatment of seed and planting stock (e.g. to combat viruses and bacteria in sugar cane cuttings), solarisation (covering the surface of the ground with plastic sheeting produces phytosanitary effects by virtue of the greenhouse effect resulting from insolation, e.g. for controlling parasitic seed plants, soil-borne harmful organisms etc.), burning-over to control weeds and burning of crop residues. Low temperatures inhibit the spread of certain storage pests.

Eradicative, protective and curative methods are used in chemical plant protection to destroy harmful organisms or keep them away from plants, to

protect plants against attack and penetration by harmful organisms and to cure plants (or parts of plants) that have already become infested or diseased. Although chemical methods can be subdivided in this way on the basis of their effects, the boundaries between the individual categories are somewhat fluid, as many pesticides have more than one type of effect. Pesticides generally kill the harmful organism by influencing vital metabolic processes or disrupting the conduction system. Selectivity can be varied through appropriate selection of the active ingredient, formulation, application technique and time of application.

Biotechnical and biological methods of plant protection have gained in significance, among other things because the risks and limits of chemical measures are today assessed more realistically. Biotechnical methods utilise the natural reactions of the (almost exclusively motile) harmful organisms to physical and chemical stimuli in order to bring about changes in their behaviour for the purpose of plant protection (e.g. light and colour traps, chemical attractants, antibodies, pheromones, hormones, growth regulators). The emphasis is on measures which aim not to directly kill the harmful organisms, but rather to permit population monitoring for the purpose of forecasting, defensive action and deterrence. The harmful organisms can be killed by combining biotechnical

methods with chemical measures.

Biological plant protection involves using organisms and their activity to protect plants and enhance their resistance to biotic (harmful organisms) and abiotic limiting factors. For the purpose of pest and disease control, beneficial organisms are specifically preserved and fostered, released in large numbers or introduced into habitats where they have not been found hitherto. Biological control of weeds has to date primarily involved introducing beneficial organisms into new habitats.

Another biological method is that of inducing resistance to disease. This can be done, for example, by infecting plants with pathogens having low virulence.

There are close links between biological and integrated plant protection in that both methods attach major importance to regulation by means of biotic limiting factors. If such methods are to prove effective, moreover, there must be little or no use of preventive and broad-spectrum pesticides. Biological methods can be applied on only a limited scale in intensively used agrobiocoenoses which are poor in species, but can play a more important role in areas where extensive farming is practised and in coenoses comprising a greater variety of species. Their

limits are determined above all by the efficiency of the beneficial organisms and the latter's dependence on environmental conditions.

Integrated plant protection is a concept which involves coordinated use of all ecologically and economically justifiable methods in order to keep harmful organisms below the economic threshold. The emphasis is on utilising natural limiting factors. The main aim is to preserve the balance of nature as far as possible; this is to be achieved by reducing use of chemical plant protection methods and simultaneously employing a variety of measures from the other categories. It is here that the links with the plant production sector are particularly close. Use of pesticides is to be reduced to the essential minimum by abandoning the practice of routine or calendar-based spraying, gearing pesticide dosage to actual conditions, refraining from the use of broad-spectrum persistent agents (liable to harm beneficial organisms) and selecting the time of application such that beneficial organisms suffer no adverse effects.

Integrated plant protection methods generally prove more successful in permanent crops than in short-lived crops, since the biocoenoses of the former are more stable and can be more permanently influenced whereas those of the latter are inevitably subject to constant change. The limits and risks attaching to

these methods become clear if the work is performed by untrained personnel. Use of integrated plant protection methods generally calls for detailed knowledge of biological, ecological and economic factors.

2. Environmental impacts and protective measures

2.1 Plant protection in general

Environmental impacts

The environmental impacts of plant protection are caused by the influence of substances and/or forms of energy on organisms and their functioning as well as on soil, water and air. The extent to which a plant protection measure is harmful, and in particular the degree to which it is liable to cause lasting harm, is determined by its varied influences on the functioning of the ecosystem. Adverse environmental impacts are likely if plant protection measures fail to take adequate account of ecological considerations. Repeated, one-sided application of a particular active ingredient will cause the harmful organism to develop

resistance to it. Although non-specific control methods curb the spread of a harmful organism, they also unintentionally affect numerous beneficial organisms. They thus adversely influence the diversity of species and biological regulation mechanisms, creating a risk that harmful organisms may multiply more rapidly and consequently necessitating additional plant protection measures. Effects on the abiotic environment are also likely (e.g. soil erosion caused by tillage carried out for the purpose of plant protection).

When combined with other plant production measures, plant protection extends the ecophysiological cultivation limits of numerous crops. Cultivation of potatoes or tomatoes in humid mountain regions necessitates increased plant protection measures for combating fungi. Plants whose underground storage organs constitute the harvested crop (e.g. potatoes, taro) jeopardise the sustainability of land use, particularly when grown on slopes, on account of the erosion risk and increased mobilisation of nutrients.

Chemical plant protection came to occupy its position of major importance by virtue of the fact that pesticides are easy to use and fast-acting. There is thus at the same time also a risk of misuse, e.g. uneconomical use of pesticides.

Socio-economic conditions can be influenced to a considerable extent by the introduction of - or changes in - plant protection methods, which at the same time constitute a key element of the production system. This is particularly true of countries whose economy is based primarily on agriculture. The transition from a cropping system incorporating fallow periods to permanent cultivation, for example, necessitates substantially increased financial outlay on weed control, giving rise to corresponding socio-economic effects. What is more, changes in the spectrum of field flora will also become apparent, with species that are more difficult to control gaining the upper hand.

The changeover from weed control by means of hoeing to use of herbicides can bring disadvantages for the population groups (children, women, men, ethnic groups) which previously performed the work. The introduction of new methods may also have an influence on health, earning capacity and standard of living. At the same time, social goals and ethical and moral concepts provide the framework within which plant protection must operate (e.g. bans on killing certain types of animal; assessment of water/air quality, freedom from residues, job safety, work preferences, leisure needs).

Protective measures

The aim of environmental protection measures is to minimise the long-term ecological damage caused by plant protection. To this end, macroeconomic goals must be weighed against microeconomic goals and the "polluter pays" principle consistently applied. The control threshold should be determined on the basis of ecological and economic criteria, taking long-term aspects into account.

Efforts should be made to achieve this goal by making extensive use of natural limiting factors (cf. environmental protection measures described in the environmental brief Plant Production) and by reducing the probability of damage (see 1. above). The potential consequences of plant protection for the production system and ecosystem, e.g. resulting from expansion of cropping to include sites with a greater risk of pest infestation, must be taken into account along with possible impacts on economic and social conditions.

2.2 <u>Specific plant protection methods</u>

2.2.1 Physical methods

Environmental impacts

Thermal methods often require the input of sizeable amounts of energy in order to kill harmful organisms through the effects of heat (burning-over, production of steam or hot water). The environmental impacts of energy generation must be borne in mind (cf. environmental briefs Overall Energy Planning and Renewable Sources of Energies). Although solarisation uses solar energy, plastic sheeting - generally made of polyethylene - has to be placed over the entire area concerned or between the crop rows in order to achieve the greenhouse effect and many countries have still to find a satisfactory way of disposing of this sheeting. The effects of thermal methods on the biocoenosis are in most cases non-selective, so that microflora and microfauna populations must then re-establish themselves and achieve equilibrium in a biological vacuum in soil which is generally pasteurised or sterilised. Mechanical weed control methods involving tillage measures will lead to changes in the soil's susceptibility to erosion, an effect which must be given particular consideration where slopes are concerned. There is also a risk of damaging plant organs and thereby creating portals of entry for mechanically transmitted viruses and secondary parasites. Both thermal and mechanical methods generally promote mobilisation of nutrients from organic matter. This humus decomposition, accompanied by the destruction of clay-humus complexes and a deterioration in the soil structure, leads to a reduction

in soil fertility. There is also a danger that nutrients may be leached out or introduced into other ecosystems. Flooding to curb the spread of soil-borne harmful organisms has a major impact - albeit only in the short term - on biotic and abiotic soil factors, with the soil structure and nutrient dynamics being adversely affected. Physical plant protection methods generally require a considerable amount of labour and their effectiveness against harmful organisms is highly limited in terms of both duration and area. Use of such methods may be restricted on account of labour shortages and for economic reasons.

Protective measures

In terms of timing, location and intensity, thermal and mechanical methods are to be employed such that they combine maximum effectiveness with minimum detriment to beneficial organisms. Where mechanical methods are used, the role played by the vegetation in protecting the soil structure and soil organisms must be borne in mind. Covering the ground with pieces of vegetable matter (mulch) is one way of controlling weeds and at the same time preventing erosion. Use of mechanical methods is promoted by the development of labour-saving and effectiveness-enhancing techniques which make it possible to avoid the damage caused by other techniques.

2.2.2 Chemical methods

Environmental impacts

The environmental impacts of chemical plant protection essentially comprise three overlapping areas:

a) acute and chronic toxic effects

b) contamination of harvested crops, soil, water and air with pesticides and their conversion products, as well as accumulation of such substances in the system

c) impacts at system level (biocoenosis)

a) Classifying chemical pesticides on the basis of target groups gives the false impression that their toxic effect is in each case limited to their target group (herbicides - plants, fungicides - fungi, insecticides - insects etc.). Most agents are non-selective and have a lethal or inhibiting effect on organisms, as they interfere with basic metabolic processes (photosynthesis, ATP (adenosine triphosphate) formation, membrane development and functioning etc.). The toxicity of

pesticides gives rise to significant impacts. The World Health Organisation (WHO) estimates that 1.5 million people are poisoned by pesticides each year, 28,000 of them fatally (54). Apart from their active ingredients, pesticides also contain additives to ensure adhesion and wettability as well as to perform various other functions. Out of 1,200 additives tested by the US Environmental Protection Agency, 50 were classified as toxic (24).

Particular risks emanate from poor-quality products, which are often to be found on the market in countries with liberal registration requirements (68). Recurrent problems include pesticides which have aged beyond the point where they can still be safely used, contamination, poor formulation and active-ingredient concentrations deviating from those declared.

Pesticides can give rise to environmental pollution during storage and transportation (soil, water, air), primarily as a result of leaking containers and subsequent problems caused by sale of large quantities.

There is also a risk of food contamination if pesticides and foods are not stored separately or are sold together, which is frequently the case in some countries.

As pesticides generally deteriorate within a short time (often less than two years), the hitherto unsolved problem of proper disposal arises. Dangerous "time bombs" exist in many countries, with sizeable quantities of pesticides sometimes concentrated in a storage area of a few square metres.

If dealers and farmers lack adequate information, knowledge and training, pesticides are liable to be incorrectly used (mix-ups, incorrect dosage, failure to observe waiting periods, etc.).

- The absence of adequate information on the containers (pictogram, labelling in a foreign language) can also result in incorrect use. Local dealers often put pesticides in food containers (fruit juice bottles, bags), while pesticide containers are frequently re-used for household purposes.
- Depending on the application technique and weather conditions, the risk of poisoning exists for pesticide users, members of their family participating in the farm work (particularly children) and neighbours. Protective clothing suitable for the tropics is virtually unavailable. Pesticides sprayed from aircraft are particularly likely to drift onto houses, neighbouring crops, pastures, bodies of water etc.

- Correct use of pesticides is based on purchase as and when needed, together with considerable outlay on appropriate storage methods and application techniques. It calls for sizeable inputs of capital.

b) Contamination of harvested crops, food and animal fodder with pesticide active ingredients or their residues and accumulation of such substances, giving rise to health risks for both man and animals [particularly likely in the case of incorrect use (see above), e.g. wrong dosages, failure to observe waiting periods etc.]. Use of chlorinated hydrocarbons on root vegetables, for example, led to accumulation in the harvested crop and intake by babies through baby food, which resulted in a subsequent ban on use of chlorinated hydrocarbons for vegetables.

- Contamination of soil, water and air with pesticide active ingredients and their conversion products: Over half of the pesticide applied is discharged directly into the atmosphere upon atomisation and is transported in aerosol form, sometimes over long distances, before rainfall washes it into the soil and water. Most of the remainder directly contaminates soil and water. The risk that active ingredients will undergo a change to the gaseous phase is particularly great in the

tropics, which is why pesticides with a high vapour pressure are unsuitable for use in such regions. Failure to take ecological and toxicological aspects into account can lead to cultivation problems at a later date and to restrictions on cropping on account of the site's toxic load (use of cuprous agents on bananas). If the soil's sorption capacity (retention capacity) is low, as is the case with sandy soils, pesticides and residues can be leached into the groundwater. Their persistence may increase with soil depth, e.g. as a result of the decline in microbial activity.

c) The non-specific action of most pesticides and their conversion products has a variety of direct and indirect impacts on biotic and abiotic components of ecosystems, even at a considerable distance from the application site. The indirect impacts in particular are generally impossible to forecast; unforeseeable "cascade effects" may occur within the functional structure of ecosystems. Pimentel (61) calculates that the damage caused to the biocoenosis in North America by the use of chemical pesticides corresponds annually to a figure of US $ 500 million. Well over half of these costs can be attributed to reductions in the number of beneficial organisms and development of resistance to pesticides.

Impacts of this type include elimination of pollinating insects and other beneficial organisms (natural limiting factors) as system regulation and control elements. Use of insecticides in (irrigated) swamp-rice systems endangers fish and entomofauna, which can be seen as an indication of the conflict between aquaculture and pesticide use. The biological activity of earthworms and nitrifying bacteria is adversely affected by the use of methyl bromide for soil disinfection.

Beneficial organisms can be indirectly affected if, for example, the population density of a pest which at the same time represents the specific basis of beneficial organisms' food supply is radically reduced by the use of pesticides. Decimation of a species can weaken the pest's biocoenotic ties, leading to increased reproduction and multiplication on a large scale. For example, use of broad-spectrum insecticides in fruit growing to combat the apple-leaf sucker led to the fruit-tree red spider mite becoming a problem, as pesticides had an inadequate effect on the latter and caused beneficial organisms to be destroyed.

Pesticides can influence a crop plant's susceptibility to a particular group of harmful organisms on which the pesticide applied has no effect (for example, where a high level of fertilising is practised use of herbicides containing triazine

or urea derivates can cause cereals to become more susceptible to mildew).

Lasting changes within the biocoenosis: Certain species remain unaffected by the agents used or develop resistance to them (one-sided use of atrazine in maize promotes weed infestation in the form of millet, while exclusive use of hormone weedkillers in cereals promotes the growth of grasses). Insecticides can also have an effect on pollinating insects. For instance, use of carbaryl to combat the mango leafhopper endangered or killed (wild) honeybees, thereby reducing smallholders' yield of honey and wax (32).

Over 400 arthropod species - half of them crop pests - have been found to have developed resistance to one or more active ingredients (10) (e.g. resistance of the boll weevil to DDT and other chlorinated hydrocarbons).

Protective measures

In countries like the Federal Republic of Germany with strict legislation on the distribution and use of pesticides, agents must not be recommended and used unless they have gone through the necessary registration procedure. This procedure yields information about a pesticide's toxicological, carcinogenic,

teratogenic and other properties as well as its effects on, and risks for, the balance of nature. Active ingredients are accordingly assigned to toxicity classes. Fields of application, suitable disposal methods, analysis techniques and the ways in which conversion products are broken down are also indicated. The FAO Code of Conduct, adopted in 1985, contains recommendations on the registration, distribution and use of pesticides. In countries such as the USA where legislation is strict, numerous pesticides involving comparatively high risks have been taken off the market (i.e. banned altogether) and/or restrictions imposed on their use in terms of time and place.

The reasons why certain products should not be used generally apply in all countries (30). In particular, use of persistent, broad-spectrum agents is internationally proscribed. The "dirty dozen" comprise the following fifteen active ingredients which should be banned in view of the substantial risks attaching to them:

Insecticides

Chlorinated hydrocarbons: aldrin, chlordane, DDT, dieldrin, endrin, HCH-mixed isomers, heptachlor, lindane, camphechlor

Carbamates: aldicarb (proprietary name: Temik)

Organophosphates: parathion (E 605)

Other insecticides: dibromochloropropane (DBCP), chlordimeform, pentachlorophenol (PCP).

Herbicides

2,4,5-T (proprietary name: Weedone)

Pesticide containers must bear a description of their content, the necessary safety precautions, the permissible form of use and suitable antidotes. It must be ensured that the information given can be understood by population groups potentially at risk. The necessary information should be given in English and at least one national language and should be backed up by pictograms on labels that cannot easily be removed. The criteria for marketing of a pesticide are determined by the users' degree of illiteracy and awareness of the potential risks.

If chemical methods are used to combat harmful organisms, accompanying

protective measures must be laid down and enforced. These minimum requirements relate above all to appropriate selection of the product to be used, the safety and functioning of the application technique and environmentally sound disposal of leftover pesticide and empty packaging.

National plant protection organisations must conduct training programmes in order to ensure that extension officers, users and everyone coming into contact with pesticides are aware of the risks involved. Internationally valid regulations governing the prerequisites for distribution and use of pesticides are to be developed and compliance with them monitored by high-level authorities.

Preference should be given to pesticides with low toxicity, a selective action and low persistence. Effects, possibilities of misuse, special regional factors, water conservation areas and ecological conservation zones must be taken into account as criteria for registration and use of pesticides. Use of dressed seed as food or animal fodder is to be prevented by means of adequate labelling. It must also be ensured that pesticide containers are not re-used for household purposes; this can be done by way of awareness-raising measures, appropriate container labelling and possible also special container design. Pesticides should be sold only in small containers holding a specific amount. Development of resistance on

the part of harmful organisms can be counteracted by changing the active ingredient used.

Unauthorised production and distribution of pesticides by pirate firms is a particular problem in many countries. This underscores the importance of stringent and effective legislation on pesticides (registration) and of enforcing strict import controls (with clearance certificates required if necessary to confirm that products are pure and in perfect condition). In addition, access to pesticides can, for example, be made contingent upon production of an official "prescription", proof of adequate know-how and use of pesticides within the framework of integrated plant protection methods.

Government subsidisation of pesticides - which is common in many countries - creates special risks as regards misuse and environmental hazards (42). It must be established whether assistance measures of this type actually reach the target group and to what extent environmentally sound use and disposal of pesticides are ensured.

2.2.3 Biotechnical methods

Environmental impacts

If harmful organisms are attracted by a stimulus or killed by combining such measures with use of a poison, other organisms can also be affected at the same time (see environmental impacts described in 2.2.2 above). Light traps attract most nocturnal winged insects. Use of noise to frighten off bird pests is non-specific and has an effect on other organisms, whose mode of life (nesting, mating, rearing of young) can be disturbed. Repeated use of growth regulators (hormones) has been shown to promote development of resistance on the part of the target organisms. There is also a risk of adverse effects on beneficial organisms; for example, bee larvae and other insects which consume contaminated pollen or the like may be prevented from moulting.

Protective measures

Non-specific biotechnical methods are to be avoided (e.g. light traps attracting all nocturnal insects). Use of noise to combat bird pests is to be restricted in terms of time and place to the extent necessary for directly averting crop damage. The times at which growth regulators are used and the technique employed are to be chosen such that little or no harm is done to beneficial organisms. Where

appropriate, use of attractants should be combined with application of insecticides. Development of resistance is to be counteracted through appropriate choice of agents.

2.2.4 Biological methods

Environmental impacts

Although the relationship between beneficial organism and host is in many cases highly specific and is thus likely to have only minor unwanted impacts, biological methods too give rise to environmental risks. Use of predators, parasites, pathogens and genetically modified organisms involves a danger that other beneficial organisms may be displaced or harmed. Indeed, there is even a risk that the biocoenosis will undergo extensive and uncontrollable changes as a result of the inherent momentum of biological processes. For instance, biological control of the coffee berry beetle with the aid of the fungus Beauveria bassiana jeopardises silk production in the coffee-growing region, as the fungus also attacks the silkworm (Bombyx mori).

In another case, a non-indigenous species of toad was introduced to combat

insect pests in sugar cane. However, these toads switched to a different source of food and themselves became an almost uncontrollable nuisance.

Where plants develop artificially-induced resistance to a pathogenic virus following initial infection with low-virulence strains of the same virus or a similar one, there is a risk of virus mutation or - if other viruses are also present - a danger of synergistic effects.

Protective measures

To prevent adverse environmental impacts, biological plant protection measures, particularly those in the field of genetic engineering, must be subject to statutory regulations and controls.

The (further) development of genetic engineering techniques in connection with which the risk of uncontrollable biological processes can be predicted or discerned beforehand is to be prevented by way of effective legislation (cf. risks arising from biological agents, as described in the environmental brief Analysis, Diagnosis, Testing). Biological pest control programmes must be subject to effective government control. Organisations to investigate and record the import

of predators and parasites are to be set up (quarantine).

2.2.5 Integrated methods

Environmental impacts

Depending on the combination of measures chosen from the range of available options, the resultant environmental impacts will be similar to those described above for the individual types of method, albeit on a far smaller scale. Economic-threshold concepts are to be further developed, taking into account their practical applicability. Where pesticides with low active-ingredient dosages are used frequently, certain strategies may well promote development of resistance on the part of the harmful organisms. To permit repeated application of plant protection measures, permanent vehicle access to a site is often necessary and there is thus a risk of damage to the soil structure, e.g. compaction in wet weather. In many cases the only way of solving this problem is to use lightweight vehicles, which require a sizeable input of capital.

Protective measures

The comments already made regarding the individual types of measures also apply to integrated methods involving a combination of individual measures from the four areas discussed above.

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3. Notes on the analysis and evaluation of environmental impacts

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Plant protection measures have a wide variety of impacts on the environment. As there are no universally applicable concepts, methods must be assessed by comparing their environmental impacts. In order to weigh up alternative plant protection methods, assessment criteria are needed. This calls for indicators which convey qualitative and quantitative impacts - including their duration - as accurately as possible so as to permit comparison (cf. environmental brief Plant

Production). The active ingredients, additives and conversion products of pesticides are analysed to establish their physical and chemical characteristics (persistence, evaporability, adsorption, desorption etc.). Reproducible measured values incorporating safety factors are used to determine their toxicity and residue properties (acute 50-values), chronic toxicity (no-effect level, acceptable daily intake [ADI]), maximum-quantity regulation (permissible level). The values serve as indicators or limits and must be compared with the actual contamination levels in foods and animal fodder, flora and fauna, soil, water and air. Synergistic and additive effects resulting from use of pesticides can be identified only by studying the relationships between environmental impacts (e.g. decline in particularly sensitive species, use of indicator plants, diversity studies etc.). These relationships are as yet known only in part and are to some extent obscured by the effects of other measures; in many cases they thus cannot be ascribed to plant protection measures alone.

Findings which have emerged during implementation of plant protection measures (e.g. depletion of resources or adverse social consequences resulting from such measures) provide pointers for additional assessment criteria.

Where negative environmental impacts are likely, it must be considered whether

these can be remedied without excessive outlay. Risks of irreversible damage must be ascertained separately and assessed accordingly. Plant protection methods have an influence on employment structures (e.g. division of labour between men and women, workload and capital requirements). Further assessment criteria can be developed on the basis of their impacts on farm structures and production.

4. Interaction with other sectors

Plant protection is linked to other plant production measures and is thus subordinate to the goals of plant production (cf. environmental brief Plant Production). Measures in the field of plant production also have a bearing on the goals and environmental impacts of the following sectors:

- **Livestock farming (fodder, quality control)**
- **Fisheries (prevention of water pollution)**
- **Agro-industry (quality standards)**
- **Health and nutrition, including drinking-water supplies (toxicology,**

residues)
- Analysis, diagnosis, testing (quality control, development, analytical techniques)
- Chemical industry (pesticide production)

Decisions on plant protection measures may therefore be influenced by measures in these areas. When assessments are being made, attention must be paid to the possibility that impacts generated by the various sectors could have a cumulative effect and thereby increase the amount of damage done.

5. Summary assessment of environmental relevance

Plant protection measures must be assessed within the context of the overriding goals of plant production, taking into account site-specific conditions as well as economic and socio-economic factors. The substances and forms of energy used in plant protection may have adverse impacts on humans, flora, fauna, foods, animal fodder, soil, water and air. Measures to control harmful organisms affect the diversity of species as well as the population density of individual species and

have impacts at system level (biocoenosis).

Numerous options are available in terms of plant protection methods. Analysis and evaluation of their environmental impacts should lead to selection of methods which are comparatively environment-friendly, thereby ensuring that undesirable or unjustifiable impacts are avoided.

Environmentally oriented plant protection strategies are characterised by targeted fostering and use of ecosystem-specific natural limiting factors, backed up by other measures from the wide range of physical, chemical, biotechnical and biological methods.

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29. Forestry

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Contents

1. Scope

1.1 General

Forestry is generally defined as utilisation of forests to satisfy human needs. Characteristic features of forestry are the extremely long production periods extending over several decades and, in the case of timber production, the fact that the product is identical with the production input. Production of commercial timber and the use of return on investment as a success criterion for forest owners, generally state authorities (cf. REPETTO), are unsuitable for integrated problem solutions in view of the socio-economic conditions.

Probably the most important aspects of forestry activities today are protection of species and biotopes and preservation of the human habitat. In virtually no other sector are the "limits of growth" demonstrated as clearly as by the global destruction of the forests. The impacts of this process are no longer confined to specific regions, but are interlinked on a global scale, as forests - along with the oceans - represent the most important terrestrial bioregulators of global cycling systems and the Earth's climate.

The tropical forest is particularly badly affected, with around 20 million hectares being clear-cut or degraded each year (cf. ENQUETE). Tropical moist forests cover

only around 6% of the land on Earth, yet they provide a living environment for over half of all species of fauna and flora and for millions of people.

Although the worldwide destruction of the forests has a wide variety of forms, causes and consequences, it can nevertheless be ascribed above all to exploitation and conversion of forest resources to satisfy short-term economic and personal interests. This form of activity eventually leads to the degradation and loss of human habitats.

This situation imposes new demands in terms of executing agency, project size and site. Holistic approaches which also include the sectors immediately related to forestry (CARILLO et al.) are therefore essential.

1.2 Subsectors

The forestry sector differs from every other sector of an economy by virtue of its production period and the fact that it produces both tangible goods and intangible benefits. It thus calls for special forms of biological production. Four subsectors are involved: planning, formation and utilisation of forest stands, and harvesting. Attention will be drawn where necessary to the special features of

tropical forest management.

1.2.1 Biological production/Planning

Biological production in the forestry sector is controlled through the various methods of forest management, agroforestry and product harvesting. The purpose of these methods is to achieve, by controlling site production potential, the management goals laid down during planning; such goals may involve production, conservation or a combination of the two.

Planning, establishment of a stand and utilisation are classed as subsectors of biological production.

All forestry planning is based on inventories (e.g. ZOEHRER), which provide the framework for forest management over a period of ten years in most cases. Apart from static elements such as timber stock, dynamic and structural elements such as increment and horizontal and vertical species and diameter distribution must also be recorded, particularly in tropical moist forests, otherwise the sustainability of yield regulation cannot be guaranteed.

In addition to measurement of quantitative stand parameters, multifunctional forest management also calls for comprehensive site mapping (e.g. DENGLER, MAYER, WENGER) which ascertains geoecological factors for each stand individually.

The combination of continuous forest inventories, site mapping and specification of planning targets is known as forest management planning, the details of which are laid down in forest management plans. The management and recording unit is the compartment. The division of a forest into compartments should reflect the topographical and hydrological differences between stands. Simple geometrical shapes are appropriate only in exceptional cases for lowland plantations. In heterogeneous tropical moist forests, division can be extended to water catchment areas (sub-catchments).

The individual management goals are laid down separately for each compartment on the basis of forest management planning and economic analyses. Apart from the traditional economic indicators such as internal rate of return, cost-effectiveness analyses (cf. FHSER, WENGER) can be used to assess the relative advantages of alternative management goals.

The function and structure of forest resources vary depending on the intensity with which they are utilised and the geoecological zone in question (MUELLER-HOHENSTEIN). The management concepts must be geared to the characteristic features of each type of resource, e.g. high and low forests, savannahs, mangroves and agroforestry systems or resources for gathering. The site-specific limiting factors - namely forest area, water, nutrients and light - restrict the scope for optimising forestry operations from the management viewpoint.

The different types of resource are closely interrelated and can complement one another in functional terms. These interrelationships necessitate integrated, interlinked planning. Storeyed, species-rich high forests of primary or secondary origin are best able to fulfil the necessary protective and utility functions over time and area. Commercial-timber plantations can alleviate demographic pressure on natural forests if the local population are involved in plantation management.

1.2.2 Establishment of a stand

Forests are regenerated by artificial or natural means at the end of their rotation periods or if they become overmature.

Planting

Artificial forms of the establishment of a stand comprise conventional afforestation on open sites (EVANS, GOOR), planting under shelterwood to fill gaps in naturally regenerated stands or improvement measures in over-used forests (LAMPRECHT). The form of soil preparation and the planting technique depend on species, soil fertility, water balance and land condition. Brushwood and felled-area flora can be placed in windrows or burned unless this appears inadvisable on account of nutrient losses and soil erosion.

Planting techniques range from hole planting in clearings and deep soils through cuvette planting ("micro catchments") on slight slopes in arid regions to terracing on steep slopes in high mountain regions. For crusted laterite soils, complete turning of the soil is usual.

Irrespective of the technique used, artificial regeneration produces forests having a simple structure and largely open cycling systems. The tree species selected are generally vigorously growing, competitive pioneer species. The number of species and the degree to which they are mixed remain low for reasons of manageability. The biotic and abiotic risks to such plantations become greater as aridity

increases (shortage of water, fire) and as soil fertility decreases, particularly on geologically old substrates in the inner humid tropics. The relatively small range of species on marginal sites is a result of natural factors.

Measures to protect stands against fire, storms, water stress, nutrient deficiencies and disease are frequently necessary (see FRANZ, for example, with regard to biological pest control). Controlled burning of organic surface layers (known as "prescribed burning") is a special plantation-management practice employed in arid regions to remove highly inflammable organic layers (BROWN, GOLDAMMER). Use of this method is restricted by the demands of soil and water conservation.

The planting stock needed for artificial afforestation is produced in nurseries, which usually concentrate on generative raising of planting stock from seed. Vegetative forms of plant production, such as propagation by cuttings, tissue cultures or seed production in seed plantations, are often capital-intensive and usually have to be carried out on a central basis by agencies possessing the necessary expertise (e.g. KRUESSMANN). It must be ensured that the consequences of genetic impoverishment can be overcome by means of an appropriate silvicultural strategy. Consumption and use of the inputs commonly

required by nurseries (land, seed, fertiliser, substrate, water, pesticides, means of transport) depend on the specifications of the forest management plans (management goal type planning) and the propagation method employed. The high substrate consumption involved in production of pot or container plants calls for careful logistical planning.

Natural-forest programmes could involve small or temporary nurseries in the vicinity of the stand, as the provenances and varieties necessary to achieve the related management goals can best be produced on a decentralised basis. Regional afforestation programmes can be supplied by large central nurseries.

Natural regeneration

Growth dynamics, phenology and adherence to the given spatial arrangement constitute criteria for selection of natural regeneration techniques (ASSMANN, GOLLEY, DENGLER, LEIBUNGUT, MAYER, WEIDELT, WHITEMORE). A general distinction is made between methods for clear-felling high forests, involving shelterwood and strip techniques, and the selection method for storeyed, species-rich stands. Special demands in terms of species protection and soil conservation arise in connection with conversion systems in tropical moist forests

(LAMPRECHT) and management of high-altitude forests (MAYER).

Characteristic of all methods are a specific sequence and number of individual fellings over a long period, with care taken to preserve the dominated stand. During the regeneration process, the soil usually remains almost totally covered. Working of the soil is generally confined to preparing the germination bed with implements such as cultivators or harrows. Prescribed burning may become necessary for regeneration of pyrophytes (cf. section on planting).

Irrespective of the method used, the outcome will ideally be stands which, both horizontally and vertically, are more or less heterogeneous, species-rich and multi-storeyed, and which have closed natural cycling systems. Such stands are highly resistant to injurious factors and there is thus little need for protective measures and artificial raising of plants.

1.2.3 Stand utilisation

In generalised terms, distinctions can be made between the following forms of utilisation:

- conventional forest management for production of timber and to realise protective functions (e.g. DENGLER, LAMPRECHT, MAYER)
- agroforestry for integrated production of agricultural and forestry products (e.g. ICRAF)
- gathering, generally in connection with non-timber products (e.g. DE BEER).

Irrespective of the form of utilisation, it is essential to control the relevant economic (e.g. McNEELY) and demographic conditions in order to prevent over-utilisation. A key role is played by forest tending, without which it is impossible to utilise the wide range of opportunities offered by multiple-use forestry.

Forest management

Distinctions are generally made between three types of forestry operation (e.g. DENGLER, MAYER):

- high forest created by means of natural or artificial regeneration, incorporating clear-felling (age-class) forest and all-aged (selection) forest

- middle forest originating from coppices and planting
- low forest originating from coppices

Low and middle forests are generally clear-cut in short rotation cycles. They are highly suited to production of fuelwood and other small dimensions for supplying local markets, provided that care is taken to implement the necessary protective measures such as regulation of forest grazing, terracing or cultivation of site-appropriate provenances. Management criteria are based on economic and technical data such as diameter and timber stock.

In high-forest management a distinction is made between final felling during stand regeneration and intermediate felling during forest tending. Long rotation periods and periodic tending measures make high forests suitable for achieving multifunctional goals such as production of high-grade timber and ensuring of welfare functions.

The purpose of forest tending is to raise stable stands by controlling the stages of stand development (e.g. MAYER). The management criteria relate to aspects of silviculture and forest yield science, such as basal area, number of trees, species and diameter distribution, or target diameter. Irrespective of the stage

concerned, control of the limiting factor represented by light is a characteristic element of forest tending (e.g. BAUMGARTNER in MAYER).

In generalised terms, a distinction can be made between young growth tending, or pre-commercial thinning, and commercial thinning. Both chemical and mechanical methods are used, the latter being performed manually or with the aid of machines. Chemical methods are feasible only if non-persistent agents can be applied on a targeted basis. Systematic methods such as row thinning are commonly employed on monotypic plantations; only in favourable locations are they unlikely to give rise to problems (soil erosion).

Selective methods, known as selection thinning (e.g. MAYER) or timber stand improvement (WEIDELT, WENGER, WLL), are the most effective in terms of yield and from the ecological viewpoint. A characteristic feature of such methods is regulation of the growing space of trees preselected for harvesting through removal of competing adjacent trees. In all-aged forests, growing-space regulation, intermediate felling, final felling and regeneration can be combined, whereas in artificially formed plantations this is possible only if at least two tree species have coordinated degrees of shade tolerance.

Tropical moist forests have special requirements where timber production is concerned (e.g. LAMPRECHT; WEIDELT; WHITEMORE 1984).Selective methods are in most cases particularly suitable for such forests in view of the diversity of species, the horizontal mosaic structure, the vertical layering, the nutrient balance (see Section 3) and the phase-controlled growth dynamics. In simplified terms, it is possible to distinguish four cyclically linked development stages (WHITEMORE, 1978): terminal stage - gap/group stage - build-up stage - maturity/climax stage. Forest regeneration and timber harvesting must be geared to these growth dynamics.

In principle, even timber harvesting in primary forests containing irregularly fruiting tree species with uneven diameter distribution is justifiable if only dying individual trees in the main stand are removed using highly mobile harvesting methods (see 1.2.4) after fruiting ("mortality pre-emption", SEYDACK 1990). In stands consisting of tree species with even diameter distribution, located on fertile and erosion-resistant sites, the trees can be removed in groups. Less selective methods are possible where stand conditions are homogeneous, as is the case for example in many natural tropical coniferous forests. However, harvesting of hitherto unutilised tree species (lesser-known species) is acceptable

only if the nutrient balance (see Section 3) remains in equilibrium and the reproductive biology of the species concerned is known.

Management of special forms of tropical forest vegetation, such as gallery forests, savannahs and mangroves, cannot be treated within the scope of this environmental brief (cf. CHAPMAN, GOLLEY et al. 1978).

Agroforestry

It is above all in the humid tropics that increasing population pressure is blurring the dividing line between agriculture and forestry. In areas on the fringes of intact forests, combining agricultural and forestry operations is often the only way of meeting the population's food and wood requirements. Agroforestry operations exhibit a higher degree of ecological stability than purely agricultural ones and in many places are the only means of permitting permanent cultivation (e.g. JORDAN).

Although there are no universally valid definitions, distinctions can be made for practical purposes between agroforestry, silvopastoral and agrosilvopastoral systems.

The degree to which agricultural and forestry elements are integrated in terms of time and area (e.g. ICRAF) depends on the available know-how, the availability of water, the soil fertility and the market. In marginal areas remote from markets it is generally possible to realise only simple forms of agroforestry, such as slash-and-burn agriculture (also known as shifting cultivation) or pasture farming in savannahs (PRATT).

Gathering

In many geologically old, tropical moist forests, gathering of non-timber products, known as "minor produce", is often the only possible form of sustainable use. This is particularly true of Central Amazonian sites highly deficient in nutrients, where intensive forms of roundwood production result in a negative nutrient balance. In many parts of South-East Asia, for example, the production value of the minor produce far exceeds that of timber production (DE BEER). As tropical forests yield an immense number of non-timber products, it is impossible to cover all the region-specific aspects of this area within the scope of this environmental brief.

1.2.4 Harvesting techniques

Forests and trees yield numerous products important to man: commercial timber, pharmaceutical products, spices, resins, rattan, foods and tanning agents. Each of these products requires a tailor-made harvesting method (CAPREZ, STAAF, DE BEER).

Timber

Of all activities in the forestry sector, timber harvesting requires the greatest input of capital and is most likely to cause damage. The strained nutrient balance means that timber harvesting is often impossible in tropical moist forests located on geologically old substrates. Planning and execution of timber harvesting must therefore be based on both economic and ecological criteria. The paramount aim of all timber harvesting measures is to minimise damage to the soil and stand. The following criteria must be taken into consideration in selecting the method to be used:

- management goal (rights of use, protective forest, commercial forest)
- stand density (number of trees, structure, nutrient dynamics)
- type of felling (intermediate felling, final felling, timber assortments)
- topography and soil (skidding distance, soil erosion)
- infrastructure (accessibility, construction costs)

From the operational viewpoint, actual felling of the trees is considered separately from hauling of the felled trunks. While mobile harvesting machines are generally used in non-tropical regions, felling of trees in the tropics is performed manually with the aid of an axe, handsaw or power saw. The degree of success is largely determined by the training and remuneration of the forest workers and by the way in which work at the felling site is organised. Resource-conserving methods of timber harvesting include the following features:

- marking of stand before felling (inventory)
- directional felling
- conversion of shortwood at the felling site before hauling

In roundwood handling, distinctions are made in organisational terms between skidding or hauling within the stand and (long-distance) timber transportation (road, rail, waterway), in technical terms between manual, animal-powered and mechanical techniques, and in method-related terms between whole-tree methods and roundwood methods. The damage done to the stand increases in proportion to engine power, intensity of utilisation, slope inclination, degree of accessibility, trunk length and the amount of ground skidding involved. Inappropriate hauling methods can cause soil compaction, rill erosion along

wheel tracks, destruction of forest soil flora and the dominated stand, and butt and root damage to the rest of the stand. The most important hauling methods are given below in generalised terms, listed in order of the potential degree of damage that may result from them:

- Ground-based methods

skidding hoists for clear-cutting, final felling, moderate or long skidding distances, suitable anywhere from lowland to high mountain regions
wheeled and tracked forest tractors for clear-cutting, final and intermediate felling, short to moderate skidding distances, hilly terrain
animals (horses, oxen, water buffalo etc.) for intermediate felling, smallwood, short distances, lowland regions

- Gravity methods

manual floating for intermediate and final felling, short distances, in high mountain regions

log chutes (wooden or earthen chutes), generally for final felling, long distances, high mountain regions

- Airborne methods

travelling winches for intermediate and final felling in high mountain regions
cable cranes for universal use
helicopters for transportation of high-grade timber

In view of the mosaic structure of tropical moist forests, timber harvesting in such regions is liable to cause damage to resources unless the methods used take account of the conditions of single-tree harvesting in groups by way of mobility, off-ground hauling and a low-density road network (HODGSON). Homogeneous forms of stand in lowland regions allow less complicated methods to be used. Full-tree or whole-tree methods are suitable only for nutrient-rich lowland sites that are resistant to erosion.

After felling and hauling, timber is stored for a short time in the forest by the side of the road until it is removed by the purchaser. It is thus not usually necessary

to protect timber stored in this way. In exceptional circumstances, for example after natural disasters, it may be essential to store large quantities of timber for lengthy periods in specially created log dumps. Steps must then be taken to limit the amount of land required and the use of pesticides and to dispose of bark shavings.

Appropriate options are to be selected on the basis of time studies, forest damage analyses and economic criteria. In addition to conventional economic assessment tools such as cost-benefit analyses, cost-effectiveness analyses (e.g. WENGER) should also be employed. Such analyses must relate to the entire rotation period (production period), rather than being confined to individual operations.

Timber harvesting can have indirect effects of environmental relevance in that it opens up forest areas in a manner permitting their subsequent use. Apart from selection of environmentally sound timber harvesting methods, an efficient forest administration capable of carrying out surveillance of forest use is essential to minimise damage to the stands.

Non-timber products

As non-timber products encompass such a broad range, the effects of harvesting them cannot be described in detail here. It is essential to draw upon available local know-how in this connection.

A distinction must be made between products harvested for the harvester's own use and those harvested for marketing, as there is generally no danger of over-use where products are intended merely to meet subsistence needs. Special precautions must be taken in harvesting tree products such as resin, bark or climbing plants (e.g. rattan), as the function of the trees as means of production or support can be permanently impaired. Harvesting of "non-tree products" such as fruit or game requires less in the way of specific management if the products in question are not to be marketed.

2. Environmental impacts and protective measures

2.1 Sector-typical influences on the environment

In terms of area, forests constitute the Earth's most important terrestrial

ecosystems. Since the "invention" of arable farming around 10,000 years ago, they have been continuously fragmented and degraded and today cover less than a third of the Earth's inhabitable land surface, extending over an area of around 42 million km^2 (STARKE). As forests can perform their protective functions only where they cover a large area, man's living environment in certain regions is in jeopardy. Four protective functions will be discussed here:

Climate regulation

Together with the oceans, the Earth's forests constitute a biological climate regulator. By means of their high evapotranspiration, they generate a large proportion of the precipitation themselves in some places. Evaporation of this water absorbs up to three quarters of the radiation energy, particularly in the tropics, and thereby prevents excessive warming of the atmosphere. Large quantities of the greenhouse gas CO_2 are fixed as well. These two climate-regulating functions can be most efficiently controlled by means of near-natural, long-lived types of forest containing abundant stocks and covering large areas. By virtue of their more favourable assimilation/respiration ratio, many temperate forest formations, such as the coastal forests in the north-west of the USA, store

up to three times as much CO_2 as tropical rainforests (STARKE, 1991).

Protection of genetic resources

Although tropical moist forests cover only a fraction of the Earth's surface (6%), they contain around 90% of all apes, at least 80% of all insects, at least two thirds of all plant species and roughly 40% of all species of birds of prey. As the majority of these species can exist only in near-natural forms of forest extending over large areas, monotypic artificial forests covering small areas are unsuitable for protecting species and genetic resources.

Soil conservation

Storeyed high forests are the most efficient biological means of soil conservation. Soil erosion and soil formation under such stands are balanced and in line with the geoecological norm. The simpler stand structures found in dry forests or grass savannahs mean that such regions differ less markedly from artificial forests. The same applies to alternative forms of forest in lowland regions. Under humid tropical conditions and in high mountain regions, the erosion rates in artificial forests may far exceed the natural soil loss rate (MORGAN).

Protection of human habitats

Rapid deforestation is constricting the human habitat, particularly in tropical moist forests, while at the same time destroying jobs. Tax concessions for large-scale projects (timber exploitation, mining, cattle rearing) can accelerate this process locally and displace the labour-intensive methods involved in traditional resource utilisation. It is thus above all in natural-forest and agroforestry projects that training and upgrading can play an important part in raising decision-makers' awareness of the relevant issues.

2.2 Sector-typical protective strategies

Forests perform vital protective functions, but at the same time require protection themselves in their function as biotopes housing a variety of plant and animal communities. However, effective protection of forests is possible only if the state, industry and the local population all have an interest in their long-term preservation. The ways in which forests are used must therefore ensure protection of forest resources and sustainable generation of added value, besides being acceptable to all interest groups involved. From the hygiene viewpoint, for example, the clearance of African savannahs infested with the tsetse fly is highly

beneficial. For Iko bushmen and other game hunters, however, it means the destruction of their living environment, while for hydrologists it means flooding in low-lying areas and for nature conservationists it represents the destruction of biotopes.

Depending on site conditions, a protective strategy in the forestry sector will include components such as the following:

- Political/economic instruments

regulating forest utilisation by interlinking protective, buffer, exploitation and settlement areas
ensuring the generation of added value through utilisation of forests by means of diversification in the producer region and reinvestment of profits, e.g. in forest-tending programmes
participative planning, implementation and monitoring of forest utilisation concepts
moratorium on timber exploitation in primary forests located in tropical and temperate zones
market-oriented incentives such as input and output taxes or

subsidies for substitutes (e.g. use of cable cranes instead of bulldozers in timber harvesting)

- Technical/ecological instruments

reducing wood consumption through improvements in wood processing
function- and needs-oriented forest management by means of silvicultural planning on a single-stand basis
simulation of natural growth dynamics and forest tending through long rest periods and natural-regeneration periods

An implementation-oriented discussion of the above elements can be found in the reference literature (cf. BMZ, ENQUETE).

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3. Notes on the analysis and evaluation of environmental impacts

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All action in the forestry sector is based on the principle of sustainability. This requires a form of utilisation which is in line with the potential of the natural resources and which preserves both the steady state of the natural cycling systems and the ecosystems' capacity for self-regulation (VESTER). Sustainability thus does not imply a constant annual yield level - in timber production, for example - but rather the achievement of goals such as ensuring species-rich natural regeneration through the use of resource-conserving timber-harvesting methods (SEYDACK et al. 1990).

As intervention by man disrupts these cycles, it is essential to use not only sustainability indicators such as annual cut but also ecological and socio-economic indicators:

Nutrient balance

Nutrient cycles are a function of stand density, soil exchange capacity, nutrient

storage and allochthonous introduction of substances via the atmosphere. As it is virtually impossible to control exchange capacity, storage and introduction of substances, management concepts must aim to minimise nutrient losses. If use of mineral fertilisers is to be avoided (since they generally necessitate use of non-renewable energy sources), nutrient losses can be offset by means of allochthonous introduction of substances only where small quantities of stem timber are removed over long production periods. Nutrient-deficient sites severely restrict production of large timber and biomass (see GOLLEY, RUHIYAT 1989 in WEIDELT 1989, ULRICH). Relevant indicators are

- nutrient reserves in kg/ha, broken down according to ecological compartments such as soil, roots, stem timber, branches and foliage, and
- nutrient flows between the individual compartments in kg/ha/a, including introduction and removal of substances.

Water balance

Water is a limiting factor in many habitats. Its availability varies according to hydrogeological and bioclimatic conditions. As these components of the natural

environment cannot be changed, the intensity of utilisation must be geared to the dynamics of the water balance in individual catchment areas. Near-natural storeyed forests are most capable of controlling the water balance. The components of the water balance - i.e. interception, evapotranspiration, run-off and groundwater recharge - can be controlled by means of forest tending and species selection (cf. MITSCHERLICH, WENGER). Depending on purpose, individual components can be used as sustainability indicators, for example to quantify groundwater recharge in arid regions.

Soil erosion

Soil erosion is essentially a function of stocking, precipitation and relief intensity. It forms part of the Earth's natural cycling system. The smallest degree of soil erosion occurs under species-rich, storeyed high forests. The indicator for soil erosion is

> **- the site-specific geological norm (kg/ha/a), which can be ascertained on ecologically undisturbed sites by means of simple field trials (e.g. FAO) or, if this is impossible in totally degraded regions,**
> **- the tolerable soil loss threshold, which can be ascertained by empirical**

means with the aid of the general soil loss equation after WISCHMEIER (e.g. in MORGAN).

Both of these indicators provide a criterion for the intensity of utilisation and the technical and biological protective measures required.

Forest area

The minimum amount of forestry land required is determined by the population's requirements in terms of forest products and the economically necessary protective functions. The amount of land required depends on site-specific factors and the habits of the local people. In addition to ecological criteria, wood requirements and wood consumption must be taken into account along with the degree of fragmentation (ELLENBERG, PIELOU) of formerly continuous forest areas. One indicator is the forest area balance, expressed (in hectares) as the difference between the existing forest area and that which is economically necessary.

In the event of changes in the intensity of forest utilisation it is essential to know the parameters serving as a kind of early warning system which make it possible

to spot new problems as soon as they start to develop. Apart from the ecological indicators mentioned above, such indicators may also be biological (pioneer plants, particular types of animal as anthropophilous species) or socio-economic (increased market supply of gathered products hitherto used only locally).

Economic assessment of forest resources involves various factors of uncertainty. Conventional monetary methods do not adequately cover the forest's indirect functions or the non-timber products generated "informally" to meet the population's own requirements. Cost-effectiveness and risk-analysis methods must therefore be used for evaluations in the forestry sector (BMZ, EWERS, KASBERGER-SANFTL).

4. Interaction with other sectors

Against the background of population growth and steady depletion of resources, it becomes clear that the core problem in the forestry sector, namely destruction of the forests in pursuit of economic interests, cannot be solved by technical means alone. Back-up measures in related sectors play a crucial part in

permitting interdisciplinary management of general conditions for the purpose of preserving human habitats.

4.1 Complementarity

Conflicts over use of resources can be avoided by ensuring that the individual sector plans complement one another. To achieve this, it is essential to raise decision-makers' awareness of the relevant issues. Implementation of comprehensive development approaches is restricted by politico-economic realities (national and international corruption, international trade agreements, function of timber exports as a source of foreign exchange for non-diversified economies). Integrated approaches employ tools such as the following:

- **population policy, for limiting population growth and mobilising young people as a potential labour force**
- **economic policy, for conserving natural resources by limiting demand and reducing debt**
- **regional planning, e.g. for implementing large-scale afforestation programmes as a means of rehabilitating the environment and alleviating poverty**

- energy policy, for conserving natural resources by enhancing efficiency and promoting the use of non-biological, renewable energy sources (solar power, water power, wind etc.)
- agricultural policy, for achieving food security through land reforms, raising of productivity and refrainment from large-scale resettlement programmes

The environmental briefs on related sectors can be consulted where necessary. Among those of particular relevance are the following:

For biological production

- Agriculture

    Plant Production and Plant Protection
    Livestock Farming

- Infrastructure

    Spatial and Regional Planning

Overall Energy Planning
Water Framework Planning
Mining and Energy
Renewable Sources of Energy
For harvesting techniques

- Agriculture

Agricultural Engineering

- Infrastructure

Road Building and Maintenance

- Trade and Industry

Timber, Sawmills, Wood Processing and Wood Products

4.2 Social environment

Socio-cultural factors play a major role in determining the success of measures in

the forestry sector. Apart from acceptance, the following factors are among the most important:

- **traditional forest utilisation rights and obligations**
- **system of social controls regulating resource utilisation**
- **target group's income situation**
- **health and food supply**
- **training**

The complexity of the social environment means that difficulties are liable to be encountered in recording sociological data. Techniques such as rapid rural appraisals (CHAMBERS) may prove useful for small-scale projects but are generally inadequate for integrated approaches.

5. Summary assessment of environmental relevance

Characteristic features of the forestry sector are the extremely long production periods and the large areas needed to permit regulation of key global cycling

systems. The impacts of management errors are thus difficult to limit in terms of both time and area, as the consequences of choosing the wrong species of tree may not become apparent until more than a century has passed.

To ensure the success of forestry measures, it is thus essential to simulate natural cycling processes. Involving the local population in the forestry production process plays an important role as a social management tool, particularly in marginal living environments threatened with destruction.

The concepts for forest utilisation must therefore be multifunctional and needs-oriented. Monotypic plantations may thus prove site-appropriate under certain conditions, for example to provide a fuelwood supply in arid regions. In general, however, integrated management goals can be achieved only in near-natural mixed forests. Negative impacts on the environment can be minimised by employing techniques which refrain from measures along the lines of clear-cutting and contribute to creating and preserving heterogeneous stands.

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Annex: Glossary of selected terms

Basal area: Total of the trunk cross-sections of all trees in a stand exceeding a minimum diameter, given in square metres per hectare and serving as a measure of the stand density.

Biocybernetics: Subdiscipline of cybernetics (from the Greek "kybernetes",

meaning "helmsman"), which describes the control and automatic regulation of interlinked, closed-loop processes with minimum energy input in biological systems

Biomass utilisation: In forestry, limited to timber utilisation in the form of full trees, i.e. stem timber including bark, leaves and branches, or whole trees, i.e. full trees plus root wood.

Biotope: The habitat occupied by an organism or community (biocoenosis) within an ecosystem, determined by physical and chemical factors

Compartment: Permanent physical unit of forest division, serving simultaneously as a unit for planning, execution and monitoring of measures .

Cost-effectiveness analysis: Comparison of operational alternatives in which the inputs are of a monetary nature but the outputs cannot be measured in monetary terms.

Ecosystem: A unit within the natural environment, consisting of a community and its habitat (biotope) and characterised by balanced cycling systems, i.e. dynamic

steady states.

Management goal: Production goal for forestry operations setting out the range and order of precedence of all requirements on the part of the forest owner and/or the general public, both material (timber, non-timber products) and intangible (soil and water conservation, nature conservation, recreation). Distinctions are made between product goals, security goals and monetary goals, with times being set for their achievement.

Management goal type: Management goal for a stand or compartment.

Savannah: Form of vegetation found in the semi-humid tropics, generally between the inner humid tropics and the latitudes marking the Tropics of Cancer and Capricorn, consisting of grassland with scattered trees and shrubs.

Silviculture: Science of forestry production concerned with systematic creation and tending of forests so as to ensure that society's material and intangible needs can be permanently satisfied

Site: Complex of location-related - i.e. natural, economic and social - factors

influencing forestry operations.

Stand: Group of trees which exhibit similar features, occupy an unbroken minimum area and all require similar silvicultural treatment.

Welfare function: Also referred to as the indirect effects or non-wood beneficial effects of a forestry operation, i.e. "production" of goods with economic relevance such as water, soil conservation and recreation.

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30. Livestock farming

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1. Scope

As a biological process, livestock farming influences, and is influenced by, the environment. With respect to the environment the aim is to change it in such a way that a maximum of food and raw materials can be obtained on a sustainable basis.

Environmental impacts vary depending on the form of livestock husbandry and type of farm involved. There are three basic forms of livestock husbandry:

- **pasture usage**
- **pasture use with supplementary feeding**

- confinement

Farming systems can be divided into the following types:

- ranches (cattle, sheep)
- traditional pastoralism (cattle, sheep, goats, camelids, equids, often mixed herds)
- smallholder livestock husbandry (cattle, buffalo, camelids, equids, sheep, goats, poultry, pigs, small animals such as guinea pigs, rabbits and bees; a farm often keeps a variety of different animal species)
- large enterprises of industrial-scale livestock production (e.g. poultry fattening, laying batteries, pig fattening, feedlots for cattle)

Fisheries and aquaculture are covered in a separate environmental brief.

Livestock farming is possible wherever arable farming is practised. It is also the only form of agriculture in semi-arid and arid regions as well as in high mountain regions in the zone beyond the arable farming limit up to the vegetation limit.

2. Environmental impacts and protective measures

2.1 Types of husbandry

2.1.1 Pasture use in general

The most noticeable consequence of grazing is the defoliation of plants by the animals, which influences the structure of the pasture vegetation and the variety of species which it contains. The precise nature of this influence depends on the type of animal concerned, the stocking rate (grazing pressure) and possibly also the time of year. Cattle and sheep tend to eat grass, whereas camels and goats prefer leaves.

An ideal sheep or cattle pasture will thus consist primarily of grass and herbaceous plants, while an ideal camel or goat pasture will contain more trees and bushes.

Grazing can stimulate plant growth and encourage the growth of creeping ecotypes of a particular plant species rather than those which grow upright. In grass/legume pastures, grazing often favours the legume component, because

animals generally prefer grass during the early part of the vegetation period; with competition reduced in this way, legume growth is promoted. However, the young stages of some legumes are also popular with animals. While light grazing and browsing on bushes and trees can stimulate growth, removal of vegetation by livestock on a larger scale can reduce growth or even cause plants to die off and may hinder regeneration of fodder bushes from seeds and suckers.

The effects resulting from trampling of the vegetation by livestock depend primarily on the type of animal concerned, the stocking rate, the soil condition and the topography. Damage caused by trampling can increase soil erosion; however, the roughening-up of the ground can also create better conditions for germination and thereby promote plant regeneration. Where the soil in humid regions is heavily waterlogged, the vegetation cover can be destroyed as a result of trampling.

The seeds of many pasture plants are very small and can pass through the animals' digestive tract without any impairment of their germination capacity. Certain plants are thus dispersed with the animals' dung. Hard-shelled seeds are also scarified and the seeds are redistributed and sown by the animals.

Only a small proportion of the nutrients and energy intake by livestock actually finds its way into the animal products used by man. The remainder is excreted via dung, urine and, in the case of ruminants, methane (a gas which plays a part in the greenhouse effect). The breakdown of organic matter in the digestive tract of ruminants gives rise to energy and nutrient losses similar to those resulting from microbial breakdown in the soil; as the breakdown process in the stomach of ruminants is considerably faster, however, the grazing animals accelerate the nutrient cycle. If the animals are penned overnight, the excretion of dung in the pen means that the pasture is deprived of nutrients. Although the dung collected in pens can be used in arable farming and horticulture or for production of biogas and can thereby contribute to improving soil fertility, the loss of nutrients can accelerate degradation of the pasture vegetation.

In semi-arid and arid regions, the considerable fluctuations in annual rainfall mean that vegetation growth varies greatly not only according to the time of year but also from one year to another. The herbaceous vegetation layer in particular will thus not exhibit consistent growth. In drought years there may be so little vegetation growth that all the herbage is eaten by the animals. If shrubs and trees are not to suffer permanent damage, the amount of their vegetation

consumed as fodder must not exceed a specific proportion of the annual growth, otherwise their capacity for survival and regeneration will be jeopardised.

Permanent damage is generally considered to have occurred when the vegetation's capacity for regeneration has been impaired and the surface of the ground has suffered erosion by wind or water. In view of the differences between plant communities and the differing regeneration capacities of the various species, it is not possible to lay down any universally valid standards specifying how much land can be used without impairing the productivity of the vegetation and what stocking densities are possible. American estimates work on the basis that 50% of the vegetation can be used, while studies from West Africa take figures of 30-50% (le Houerou 1980). Others graduate permissible vegetation use according to rainfall and take different levels of permissible utilisation for the bush/tree layer (25-50%) and the grass/herbaceous layer (30-50%) (Schwartz 1989). Factors which can assist in assessing degradation include the age structure and species composition of the tree and shrub community, seed reserves in the soil for the herbaceous plants and possibly also soil cover as well as depth and condition of the A-horizon.

The distribution of animals in an arid pasture area is determined primarily by the

availability of water. Deep wells containing plenty of water supply a large number of animals and may thus give rise to serious overgrazing in their immediate vicinity. The size of the area around a well that can be used by animals for grazing depends among other things on the dry-matter content of the fodder, the type of animal and the animals' physiological status. Inadequately protected wells and watering places can easily be contaminated by dung and may also constitute a health risk for the local population if drinking water becomes contaminated. The concentration of animals around wells can promote the spread of epizootic diseases. Around every watering place there is a certain area which, although it contains an accumulation of nutrients by virtue of the dung produced by numerous animals, is almost totally devoid of vegetation as a result of trampling. The size of this area depends on the design of the watering place (e.g. troughs on hard ground) and the way in which access to it is controlled (e.g. fencing-in of watering places). Use of fertiliser in arable farming and horticulture in the vicinity of the watering place will not give rise to any problems.

Pastureland comprises natural pastures, fallow land and harvested fields. Forested areas, which in some cases are under the control of forest administrations, can also be used as pastures. In many cases, for instance in

North Africa, the major proportion of the forest yield is derived from livestock farming. Fodder production is an integral part of agroforestry. It must be pointed out, however, that forest pastures are often over-used. If this is to be prevented, a wide variety of measures are necessary: reduction of tensions between forest administration and local farmers; employment of an adequate number of appropriately motivated personnel in order to enforce the regulations limiting pasture use; provision of alternative fodder resources for local livestock owners; steps to prevent use of pastures by non-local livestock owners not engaged in agriculture; reasonable charges (where payment is made for use of forest pastures) by comparison with the price of other fodder resources; and involvement of the local population in pasture-use planning. Both the dry and humid tropics offer examples of balanced pasture management which takes forest growth dynamics into account.

2.1.2 Pasture use with supplementary feeding

The environmental impacts of supplementary feeding depend on the context and the type of feed. Where fodder is of poor quality but available in large quantities, supplementary feeding of minerals can improve utilisation of the "standing hay". Provision of supplementary feed in the form of feed concentrate or high-quality

roughage soon leads to a reduction in the amount of fodder consumed per animal during grazing, which benefits the pastureland. If, however, the number of animals is increased on account of the improved fodder supply and the natural pasture continues to be used, there is a greater risk of degradation. In some cases (e.g. in North Africa) livestock are given so much supplementary feed that this feed covers not only their performance requirement but also part of their maintenance requirement. Another reason for overgrazing is the desire to improve the quality of the animals' meat, since this will be reflected in higher meat prices. Meat quality is influenced in particular by the fact that the animals move around more and by the improved basic fodder supply.

2.1.3 Fodder production

Erosion-control strips can be used for fodder production. Appropriate planting of permanent fodder crops (such as sulla in North Africa) can serve as a form of "soft" erosion control. Fodder growing within a crop rotation system can have positive effects on soil structure and soil fertility (see Plant Production). The possibility that fodder crops may compete for land with crops that can be used as food for human beings must be borne in mind.

In the case of certain fodder crops, a large quantity of nutrients is taken from the soil together with the green matter. If these nutrients are not replaced, or if the dung is not returned to the field, there is a danger that the nutrient balance may be disturbed. If mineral fertilisers and herbicides are used in fodder production, there is a risk that surface water and groundwater may become contaminated and that the diversity of species may be reduced at the same time.

2.1.4 Confinement

While pasture use primarily involves ruminants, chickens, pigs and small livestock such as rabbits and guinea pigs are generally kept in confinement.

The environmental impacts of keeping livestock in confinement depend on the number of animals, the type of animal, the nature and origin of the feed and whether the livestock housing is open or closed. The environment prevailing in the animal-sheds (temperature, humidity, light, presence of noxious gases, dust and germs) has an effect on the animals, while livestock housing itself has an effect on its immediate environment through odours, liquid manure and noise. Where ruminants are kept, methane (a gas which plays a part in the greenhouse effect) is also released.

If livestock are kept in confinement, the vegetation suffers far less damage than if the animals are allowed to graze. However, use of cut fodder means that the soil is deprived of nutrients on a considerable scale; if these nutrients are not replaced, there is a danger that soil fertility may be reduced.

The enormous quantities of liquid manure produced where a large number of animals are kept can impair drinking-water quality and contaminate both surface water and groundwater. Large-scale chicken farms located near cities give rise to particularly adverse environmental impacts on account of their need to dispose of dead birds and droppings. Liquid and solid manure represent a major potential source of infection - especially for children - in many developing countries, particularly if no measures are taken to prevent contact with them. When used as fertilisers, liquid and solid manure can have a beneficial effect on soil fertility and soil structure, provided that they are not applied in excess.

2.2 Farming systems

2.2.1 Ranches

Ranches permit uniform management of comparatively large areas. Large-scale

farms of this type nevertheless do not guarantee conservationist use of pasture resources (Harrington et al. 1984). In dry years a ranch too requires alternative fodder resources or the number of animals must be reduced in good time, otherwise heavy losses are likely. Supplementary feeding can lead to over-use of pastureland and thus increases the risk of erosion. When a large farm with "rational" stocking rates or a pasture reserve with a controlled stocking rate is established in an area where traditional livestock husbandry predominates, it should be borne in mind that although the reduced stocking rate on the land concerned may be more appropriate to site conditions than the original rate, the exclusion of animals from this land will increase the grazing pressure in the surrounding area.

Particularly in humid regions, large-scale land clearance to create pastures for ranches substantially reduces the diversity of species found in the vegetation. Apart from the resulting erosion problems, there may also be a risk of climatic changes over a wide area. The fact that ranches generally keep only cattle gives rise to one-sided utilisation of resources, which either permits only very low stocking rates or calls for sizeable inputs to preserve the pastureland. There is also a danger that the pastureland may be acidified as a result of waterlogging.

Damage caused by trampling can have an adverse effect on the soil structure, leading to increased surface-water run-off and a greater risk of erosion.

Although ranches can improve the urban population's food supply, their carrying capacity per unit of area is smaller than that of traditional farming systems (e.g. Cruz de Cavalho 1974, de Ridder & Wagenaar 1986).

Environmental protection measures are difficult to realise where ranching is concerned. Attempts to standardise the carrying capacity of pastures are the subject of considerable dispute on account of the complex interrelationships and numerous variables involved, particularly in assessment of vegetation (e.g. Sandford 1983).

Some systems, such as those found in Australia, are based on detailed long-term studies and official determination of the permissible maximum stocking rate. As the land in Australia is generally not in private ownership, but is instead leased out by the government on a long-term basis, specific conditions can be imposed and the lease revoked if need be. In many countries the necessary data are not available and monitoring institutions are either non-existent or not equipped to perform the essential tasks. Rules aimed at preventing erosion should be worked

out together with the ranch managers concerned.

2.2.2 Pastoral systems

In such systems, animal husbandry is the sole or principal economic occupation. Herding and a high degree of mobility make it possible to utilise resources in a manner complementing arable farming or to utilise areas that can be used for grazing only at certain times of year.

Pastoralists often keep mixed species herds, which permits intensive use of a wide variety of fodder resources. The products derived from the herds include milk, meat, traction power and manure.

Integration of grazing and arable farming

Where pasture resources are used in combination with arable farming, the amount of land available for grazing varies greatly in the course of the year. During the growing season only natural pasture and fallow land can be used for grazing, while during the dry season harvested fields are also available for this purpose. Grazing has a variety of effects on fallow land and natural pasture. The

species composition of the vegetation may change in such a way that a larger proportion of the vegetation can be used as fodder or for other purposes; at the same time, however, intensive grazing can also lead to degradation. If herded animals are penned at night, nutrients accumulate in the night paddock as a result of the droppings and urine produced by the livestock. These nutrients can be used to preserve soil fertility on arable land (dung), but are thereby removed from the nutrient cycle on the land used for grazing. Leaching from the night paddock can lead to contamination of surface water and groundwater. Use of crop residues as fodder may accelerate the nutrient cycle and result in redistribution of nutrients in a particular field or among fields. If crop residues are used on a large scale the soil cover may be reduced and this can lead to erosion. Rights to use fodder resources must be established through agreements between pastoralists and arable farmers.

Mobility

A high degree of flexibility and mobility is required on the part of the pastoralists in order to permit ecologically appropriate and economically sound use of arid regions. Mobility in turn calls for large herds. In the course of their migration the pastoralists and their families must for the most part live on the products which

they can derive from their herds. Reduced mobility generally leads to overgrazing, accompanied by increased soil erosion, in the area around the newly created settlements and to under-use of other areas. Under-use can also give rise to changes in the balance of species and reduce the vegetation's productivity.

As herds and people become increasingly sedentary and concentrated in specific areas, use of green twigs and branches to construct livestock paddocks and as domestic fuel leads to destruction of the woody vegetation.

Grazing rights

Land and pasture use rights may comprise seasonal rights of use in specific areas and grazing rights in areas located a long way from one another. Apart from creating an opportunity to use land resources for grazing as well as for arable farming, this also helps to balance risks, as rainfall in arid regions is often highly localised. Communal grazing rights predominate in such areas. Communal pastures are traditionally used by clearly definable groups of livestock owners. Depending on the

group's structure and effectiveness, this makes it possible to stipulate stocking

rates and times at which the pasture is not to be used. In regions such as East Africa, controlling access to water is an important means of controlling stocking rates. Open access pastures - frequently equated with common pasture - offer virtually no opportunity for such a step. In such a context, creation of watering places outside the traditional structures can encourage opportunistic use and thus contribute to overgrazing. The secondary consequences of such a development will be degradation of the vegetation, reduction of the soil's rainwater infiltration rate and increased soil erosion.

Changes in ownership

Changes in the herd ownership structure can likewise adversely affect the pastoralists' resource management. When herdsmen look after cattle owned by other people, for example, they are often allowed only to use the milk. In order to have a secure livelihood they require large herds of their own if they are not to become impoverished. Moreover, the owners' desire to keep a check on their property may cause them to restrict the herdsmen's mobility and thus also their flexibility where pasture management is concerned. This too can result in over-use of the vegetation (disturbance of the balance of species within the flora, disturbance of the water balance, soil erosion).

Division of labour

In pastoral systems, the men are generally responsible for management and marketing of the largestock, while the women frequently tend the small ruminants and have responsibility for milk processing and marketing. The women's role is often underestimated, as it is the men who represent the family vis--vis other people. The decentralised processing and marketing of milk ensures a relatively reliable milk supply in rural areas, even though a woman may process and market only a few kilograms of milk a day. When milk is processed at household level, consideration must be given to possible hygiene risks (e.g. danger of infection).

External influences

Pastoral land use frequently necessitates agreements between various population groups. External influences - and that includes government programmes - may disturb the often fragile equilibrium. If, for example, arable farming is expanded onto land used by pastoralists for dry-season grazing or as reserve pasture, the loss of this pastureland can increase the pressure on other areas and lead to overgrazing. Should the arable farmers start to keep livestock

on a larger scale, the pastoralists

may find themselves driven out into marginal areas. This not only has consequences in terms of grazing management and livestock productivity but can also affect the welfare of the population groups concerned.

If their mobility is restricted, pastoralists may be forced to make intensive long-term use of marginal areas on a scale which exceeds the natural carrying capacity.

The resultant degradation process intensifies competition for the decreasing fodder resources. By promoting over-use of the available land it also reduces the number of species found locally and marginalises large sections of the pastoral population.

2.2.3 Smallholder livestock husbandry

The number of livestock owned by a smallholder can range from a few small animals (e.g. chickens) to large herds, e.g. twenty goats or ten head of cattle. Livestock management normally takes second place to the interests of arable farming. Many smallholders keep more than one type of animal.

Smallholders generally use pastures with supplementary feeding (at least on a seasonal basis) or keep their livestock in confinement. Large herds - such as village herds - may be mobile (cattle placed in the charge of a herdsman by their owners).

The animals may be allowed to graze freely, or may be herded, tethered or kept in fenced pastures. The practice of fencing off pastures with wooden posts - which may have to be replaced at frequent intervals on account of termite damage - can have adverse effects on the species composition and density of the tree stand. By contrast, use of "living fences" or hedges to subdivide pastureland has positive effects on the tree stand but requires a considerable amount of labour.

Clearing land to create improved pastures can increase the erosion risk and thus have an adverse influence on soil fertility. Creation of improved pastures, particularly with legumes, can be integrated into ley farming (seeded pasture rotation) and will improve soil structure and fertility. Competition for use of fodder resources may arise between livestock owners, above all between pastoralists and smallholders as well as between the smallholders themselves, and can thus impose increased pressure on the available land.

As in pastoral systems, management of largestock is frequently the men's responsibility, while the women are in charge of the smallstock. As women in many rural societies have no land ownership rights, livestock husbandry plays an extremely important part in enabling them to accumulate capital. The income earned from animal husbandry can be used to finance necessary expenditure for arable farming (fertiliser, seed, hired labour, creation of erosion-control strips), while the animals' dung can be used to preserve soil fertility. Livestock perform a particularly important function as a form of "risk reduction" in regions where arable yields tend to be unreliable. If the harvest is insufficient to meet the family's subsistence requirements, animals can be sold to permit the purchase of staple foods. Without this means of offsetting risks it would be necessary to extend the area under cultivation, which would have negative effects in terms of soil erosion, soil structure, nutrient balance and diversity of species.

A changeover from pasture use to keeping livestock in confinement can have beneficial effects on the diversity of plant species and assist in preventing erosion. The increased concentration of liquid manure and dung may lead to greater pollution of surface water and groundwater. Keeping livestock in confinement requires more labour than pasture use and it is generally women

who are called upon to perform the extra work.

High-performance animals have more demanding requirements in terms of fodder supplies and veterinary care. If chemoprophylaxis is necessary, pathogen strains resistant to the chemotherapeutic agents used can develop (see environmental brief Veterinary Services). Introduction of high-performance animals frequently does not lead to a reduced number of livestock; it does not lessen the burden on the available fodder resources either.

The actual and potential advantages of indigenous breeds and species are often underestimated. With a one-sided promotion of the use and importation of high performance animals, there is a danger of losing genetic resources adapted to the natural environmental conditions.

Urban livestock husbandry can be regarded as a special category of smallholder livestock husbandry. As urban livestock owners purchase far more fodder than those in rural areas, their existence can encourage fodder growing in the vicinity of towns. This can have positive effects on soil structure and fertility, besides boosting the fodder growers' income. Dairy cattle are kept in urban areas to supply the urban population with fresh milk. While other animals are kept

primarily to meet their owners' food requirements, they can also serve as a form of "savings bank" and as a means to accumulate capital. The dung produced by the animals can help to improve the soil structure and nutrient balance, but may well give rise to direct and indirect health risks if it is used or disposed of incorrectly. As in rural areas, women make an important contribution to urban livestock husbandry, although it can be assumed that the division of labour between the sexes is less strict than in rural society.

Smallholder animal husbandry also includes beekeeping. Apart from producing honey, bees can substantially increase fruit yields by pollinating the blossoms and help to preserve the diversity of species within the flora. Modern intensive beekeeping involves chemical control of pests (mites etc.); such measures can create health risks for humans if the chemical agents are incorrectly used and if residues find their way into the honey. Importing of higher-performance strains of bee can eradicate indigenous species. Production of honey and beeswax, which is predominantly a male domain, can be a highly profitable source of income in rural areas.

Environmental protection measures in the field of pastoral and smallholder livestock husbandry may involve steps to change framework conditions or direct

intervention. Examples of measures aimed at changing framework conditions include discontinuation of subsidies for feed grains - in North Africa such subsidies contributed to widespread overgrazing - and changes in land law (land reform). Where direct intervention in pastoral and smallholder production systems is envisaged, it is essential that the groups affected be involved in the measures right from the planning stage. The measures planned may relate to a wide variety of different areas, e.g. water resources management, erosion control, fodder growing or - where smallholders are involved - promotion of confinement. Simply demanding a reduction in the number of animals - as was frequently done in the past - reflects an inadequate understanding of the way in which pastoral and smallholder production systems function.

2.2.4 Large enterprises with intensive animal production (commercial farming)

Large-unit animal production generally does not depend on the availability of land to provide forage, as fodder is imported from other parts of the country or from abroad. For the purpose of supplying the urban population, large-scale livestock production focuses on pigs and poultry.

Large farms consume far more fossil energy per product unit than traditional

farms. If growth stimulants such as antibiotics or hormones are added to the fodder, there is a danger that residues may be found in foods of animal origin and that resistant pathogens may develop.

The high water consumption of large farms is also likely to lead to excessive utilisation of scarce water resources.

In confinement housing, the prevailing in-house-micro-climate (temperature, humidity, noxious gases such as ammonia, hydrogen sulphide and methane, dust and germ content of the air) can have adverse effects both on the animals and on the farm workers (health risks). The mere size of the farms means that the danger of surface water and groundwater being contaminated by liquid manure and farm effluent is far greater than in the case of smallholdings. The problems attached to the disposal of dung and animal carcasses are also likely to be greater, as is the related hygiene risk. Use of disinfectants can endanger water, soil and possibly also health.

Where cattle are involved, sizeable quantities of methane - a gas which plays a part in the greenhouse effect - are produced in the animals' stomachs and released.

If large farm enterprises are in competition with smallholdings, they can have an adverse effect on the smallholders' income. This may force smallholders operating under marginal conditions to engage in arable farming instead of livestock husbandry. Apart from giving rise to undesirable consequences with regard to the balance of species and soil fertility, such a step also increases the danger of erosion in the region concerned. Some large farms, such as commercial cattle-feed lots or large dairy farms (agricultural combinates), may also compete directly with smallholdings for agricultural land (e.g. in irrigated areas) and thereby force the smallholders into marginal areas. However, this risk is greater in the case of plantations and other crop-growing farms than in the case of livestock farms.

Environmental protection measures on large farms with intensive livestock management focus primarily on technical aspects: housing design, whole farm layout, ventilation, distance from settlements, precautions during storage and disposal of liquid manure and dung, hygiene measures such as disinfection, ban on use of growth stimulants, fencing-in of livestock housing etc. Technical standards in Central Europe are well documented (e.g. the German DIN standard 18910 on controlled environment in livestock housing, specifications laid down

by the Association of German Engineers [VDI], maximum workplace concentration values (MAK), construction specifications issued by the German committee on technology and construction in agriculture [KTBL]).

3. Notes on the analysis and evaluation of environmental impacts

There are no generally applicable guidelines for analysing the environmental impacts of livestock farming. Useful background information concerning the impacts of large farm enterprises on water and the environment prevailing in the livestock housing can be obtained from German guidelines (e.g. DIN standard 18910, VDI specifications, planning documentation for livestock housing). Australian studies (e.g. Harrington et al. 1984, Squires 1981) can yield valuable pointers concerning ranches and pasture use in general. Collection of data to ascertain the impacts of livestock farming must be conducted on a long-term basis and can involve a variety of methods such as soil and plant monitoring, investigation of herd composition and livestock productivity, interpretation of aerial photographs (series) and possibly also interpretation of satellite images. An ecosystem analysis provides a sound basis for determining the carrying

capacity of the ecosystem in question.

The ecological, economic and technical rationale of pastoral and smallholder livestock farming has sometimes been the subject of heated debate in recent years (Sandford 1983, Galaty et al. 1979; see also articles published within networks such as Nomadic Peoples and ODI Pastoral Development Network or by CRSP). The current state of knowledge does not permit any form of definitive assessment; the information sources cited above should instead be seen as offering pointers.

4. Interaction with other sectors

Livestock farming is interlinked above all with plant production and forestry and constitutes an element of general resource management. One link with plant production lies in the "transformation" of feedstuffs such as green forage, crop residues and cereals. Production and spreading of dung has beneficial effects on plant production, while the role played by livestock farming as a form of "savings bank" and as a means of accumulating capital can also permit investments in

crop growing. The land requirements of pasture use are most likely to conflict with those of crop growing where the latter involves cash crops such as cotton and other crops cultivated in large-scale monoculture systems. Livestock farming also has a certain bearing on rural water supplies.

As natural pasture is often the major source of fodder for ruminants, the interests of livestock farming and pasture use must be taken into account in regional planning. Failure to understand livestock husbandry systems and the way in which they function can give rise to serious conflicts.

Food production and the related hygiene risks have an influence on the population's nutrition and health. Direct competition regarding product use can arise if cereals and other products that could be competition by humans without further processing are fed to livestock. Indirect competition occurs wherever feedstuffs (e.g. soya beans) are grown on a large scale for export, since this is to the disadvantage of smallholders engaged in livestock husbandry.

Livestock farming supplies raw materials for further processing by dairies, slaughterhouses, tanneries and spinning mills and is thus a source of raw materials for agro-industry.

Where draught animals are kept, livestock farming supplies "products" required in agricultural engineering; large farms are customers in this sector by virtue of their need to purchase items such as equipment for installation in livestock housing. Veterinary medicine essentially performs a service function for livestock farming. Fishery yields fish meal and thus also supplies feedstuffs for other forms of intensive livestock farming, while aquaculture can utilise wastes and by-products from livestock farming.

In the processing sector, environmental impacts depend on the nature and size of the enterprises concerned. With regard to slaughterhouses, see the environmental briefs Veterinary Services, Slaughterhouses and Agro-industry.

5. Summary assessment of environmental relevance

The environmental impacts of livestock farming are determined by the intensity of the production operations.

The following critical influencing factors are to be found in all farming systems

and forms of animal husbandry:

- **land clearance for the purpose of pasture improvement or to permit forage growing**
- **stocking rate, which is influenced by the number of animals, the herd composition in terms of species and classes of animals, and the availability of fodder**
- **availability of water as a function of the number of watering places per unit of area, the distribution of watering places in the region and the design of the watering places.**

However, the extent of the environmental hazards created by these critical influencing factors depends on the farming system in question. Stocking rate, for example, becomes less important in intensive livestock farming systems; at the same time, an increasingly significant role is played by critical factors in fodder growing such as type of fodder, form of use and fertiliser application, as well as by dung removal and possibly also residues in feedstuffs and animal products (which may also be the result of veterinary measures).

The greatest environmental hazards are caused by industrial-scale animal

production. Apart from the considerable risk of water and air pollution through noxious gases and disposal of dung and liquid manure, its energy and water requirements can also be seen as having adverse impacts on the environment.

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31. Veterinary services

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1. Scope

Veterinary services are of even more immediate relevance to the environment than is the case for sectors such as plant or animal production. Their principal purpose is to preserve or restore animal health and their environmental impacts are thus essentially positive. However, the possibility of negative impacts - generally of an indirect nature - cannot be precluded. The veterinary sector primarily performs a service function for livestock farming and fisheries, as well as playing an important role in food inspection.

Activities in the veterinary sector cover the following areas:

- diagnosis and control of diseases, involving treatment, prophylaxis, vector control and epizootic-disease control
- artificial insemination and embryo transfer
- laboratory activities, comprising laboratory diagnostics, vaccine production and residue analysis
- food inspection, above all meat inspection in slaughterhouses and food hygiene.

In the fields of disease diagnosis, treatment and vector control, a distinction can be made between "modern" measures carried out by formally trained veterinary surgeons and traditional practices employed by the animal owners themselves or by healers.

In the agro-industry sector (meat and milk processing, fodder hygiene), veterinary services perform a monitoring function. Veterinary medicine is also closely linked with the pharmaceutical industry by virtue of its need for drugs and vaccines.

2. Environmental impacts and protective measures

Veterinary services perform a vital function through their key tasks of combating animal diseases and ensuring that foods of animal origin comply with the necessary hygiene regulations. Measures to protect health and the natural environment are necessary above all wherever veterinary drugs and pesticides are liable to have side-effects, leave residues or be used incorrectly or negligently, as well as in laboratory work and vaccine production. Disposal of wastes and of possibly infected carcasses (or parts thereof) unfit for human consumption is

discussed in the environmental brief Slaughterhouses and Meat Processing.

- For drugs, the following principles should be applied: strict controls on sale and use; monitoring of production if necessary; livestock owners to be advised on potential side-effects; greater emphasis on use of traditional remedies. Although traditional remedies derived from plants may not be totally free of environmental hazards, they are in general likely to have less environmental impact than "modern" pharmaceuticals. Changes in livestock husbandry systems can also help to reduce the need for drugs.

- In prophylaxis and vector control, the following measures are essential: refrainment from use of products which are broken down in the environment only very slowly or not at all (e.g. DDT); greater emphasis on epidemiological aspects and promotion of forms of livestock husbandry likely to reduce parasite infestation.

Veterinary measures may interfere with established social structures, with adverse effects on the producers' rights and income. Women are particularly liable to be affected, since in many societies they play an important role as traditional healers, as livestock owners and in the processing and marketing of

animal products.

2.1 Disease control

2.1.1 Diagnosis and treatment

Clinical diagnosis and treatment are carried out on the one hand by the animal owners themselves or by traditional healers, and on the other hand by formally trained veterinary surgeons. Clinical diagnosis has little direct impact on the environment (see environmental brief Analysis, Diagnosis, Testing).

Traditional methods of treatment often involve user-prepared plant extracts, although modern drugs are also used on a growing scale. Use of plant extracts (generally in aqueous form) can have undesirable effects on the diversity of species within the flora if medicinal plants are gathered in such large quantities that their existence as a whole is jeopardised. It can be assumed that "natural" remedies leave few residues.

Improper storage of modern drugs (chemotherapy) can have harmful effects on the environment. Certain drugs such as potent antibiotics are used too

frequently or in incorrect doses; this can cause pathogens to become resistant to the antibiotic used and necessitate administration of a number of different antibiotics in rapid succession.

There is also a danger that drugs or drug residues may accumulate in products destined for human consumption - thereby giving rise to health risks - if the prescribed waiting periods are not observed before animals are slaughtered or used for other purposes (e.g. to obtain milk).

Practices such as using waste oil to treat dermatophiliasis can bring animals short-term relief but may cause contamination of water and soil.

Getting rid of disposable cannulas and containers made of plastic and other synthetic materials can give rise to problems. Incineration pollutes the air (e.g. with dioxins), while incineration residues may contaminate water and soil.

Successful treatment of sick livestock can lead to an increase in the number of animals; this in turn may result in over-use of fodder resources, giving rise to a greater risk of erosion and general degradation of fodder bushes, fodder trees and pastureland.

Where malnutrition is a contributory factor in disease, control measures should be combined with improved feeding.

2.1.2 Prophylaxis

Immunoprophylaxis

Isolated immunoprophylaxis for infectious diseases (vaccination) can result in an increase in the number of livestock, leading to overgrazing. A shortage of fodder can in turn weaken the animals and eventually lead to their death.

The disposable equipment used (syringes, cannulas, vaccine containers) has direct impacts on the environment. Improper disposal creates a risk of injury for human beings and animals (cannulas), while disposal on landfill sites can contaminate water and soil. Waste incineration causes air pollution and incineration residues may accumulate in soil and water.

Chemoprophylaxis

Chemoprophylaxis involves preventive treatment such as daily subtherapeutic

doses of a vermifuge or prophylactic administration of trypanocides. Such treatment can also help animals adapt to new surroundings, for example new pastures, by enabling them to develop premunity. Chemoprophylaxis enables particular species or breeds to use pastureland on which they could not be kept previously, e.g. by making it possible for zebu to graze in areas infested with the tsetse fly.

However, chemoprophylaxis can cause pathogens to become resistant to the drugs used. It may also adversely influence the development of immunity or premunition, with the result that mortality will rise after chemoprophylaxis is discontinued until the animals have developed immunity of their own.

To prevent tensions from developing between population groups, veterinary measures must pay equal attention to the needs and interests of all groups concerned.

Preventive management measures

Preventive livestock management measures that can reduce the animals' risk of infection include the following:

- appropriate herd distribution: depending on the varying spread of diseases specific to particular types of animal, certain areas are used only by cattle and small ruminants, or only by camels.

- avoidance of specific pastures (at particular times of the day or year, or throughout the year): if pastureland is not used in the early morning when the grass is wet, invasion by infectious larvae of gastro-intestinal parasites will be reduced. Areas with a large population of mosquitos and biting flies during the rainy season are only used for grazing during the dry season or not at all. Areas infested with worm eggs and larvae or ticks in various stages of development (e.g. abandoned paddocks) are avoided for a number of months.

- keeping livestock away from moist pastureland: this prevents worm infestation (liver fluke) and reduces the risk of such parasites being transmitted to man.

- during migratory herding, areas infested with parasites (worm larvae, tsetse flies, ticks) are avoided at the times of year when the parasite population is at its largest (Sutherst 1987, Sykes 1987).

These preventive practices have long been employed by ethnic groups engaged in

traditional animal husbandry. They have extensive beneficial effects on biodiversity and pasture resources, as they ensure that pastureland is not over-used.

Drainage of land for the purpose of creating specific forms of landscape and vegetation can lead to the loss of wet biotopes. Both biodiversity and the landscape will benefit if wet areas are fenced off and not used for grazing.

A changeover from pasture farming to confined livestock raising in the interests of animal health (see environmental brief Livestock Farming) will increase the livestock owners' workload. At the same time, however, the fact that grazing is replaced by growing and cutting of roughage may help to reduce the risk of erosion.

The resistance of productive livestock can be enhanced by improved feeding, in particular by giving the animals high-energy and protein-rich feedstuffs along with minerals. The environmental impacts of pasture farming with supplementary feeding are treated in the environmental brief Livestock Farming.

2.1.3 Vector control

Vector control involves attempting to change the balance of species so as to hinder the transmission of diseases by intermediate hosts and vectors or interrupt the cycle of transmission to man and livestock.

Chemical control of vectors includes measures such as use of insecticides in dips and the like to combat ticks, large-scale or targeted spraying of insecticides to control flies and mosquitoes, and application of molluscicides to kill snails. Long-term use of such methods can cause resistant strains of parasite to multiply, with the result that in tick control, for example, the agents used (acaricides) must be changed at frequent intervals. There is also a danger that other arthropod species may be affected as well. Pesticides may contaminate soil and water and, if the specified waiting periods are not observed, leave residues in milk and meat. The acute and chronic toxicity of the insecticides used thus creates direct risks for both man and animal. Large-scale vector control measures, such as aerial spraying of insecticide to combat the tsetse fly, involve an additional problem, namely disposal of the insecticide containers. Such containers must be treated as hazardous waste and must not be used for storing or processing food.

A further disadvantage of chemical vector control is that indigenous animal populations may lose their natural resistance or premunity with respect to

numerous diseases. If the continuity of chemical vector control is not guaranteed, man and animal frequently have an increased risk of contracting the disease transmitted by the vector.

Unlike large-scale chemical control measures, use of attractants and insecticide-impregnated traps - for example in tsetse control - admittedly does not lead to eradication of the vector but at the same time ensures an almost total absence of insecticide residues. There is also virtually no danger that livestock will lose their premunity. Biological control methods such as use of sterilised flies to combat the tsetse fly and screw-worm fly generally do not entail any risks apart from those attaching to the necessary radiation treatment in the laboratory.

Targeted attempts to eradicate wild animals serving as a "reservoir" for pathogens causing particular epizootic diseases destroy the diversity and balance of species within the wild fauna. By reducing opportunities for hunting, they can moreover jeopardise the income and food supply of specific population groups.

Land clearance has far more complex impacts. By destroying the habitat of tsetse flies and other insect pests it reduces the infection risk for both man and livestock. The balance of species will change, with grasses and herbaceous plants

becoming dominant; at the same time there is a risk of increased soil erosion and a reduction in the soil's water retention capacity. Local clearance techniques which - like those used in West Africa - leave 30 to 50 trees standing per hectare and allow the topsoil to remain largely intact have considerably less environmental impact than technically sophisticated methods. The pastureland created through clearance is highly susceptible to erosion if overgrazed. However, land clearance can also help to alleviate the pressure on overgrazed areas, thereby reducing their erosion risk and enabling the vegetation to recover.

Bush fires are seldom started with the aim of improving animal health. A reduction in the presence of vectors such as ticks (West 1965) is merely a side-effect of such measures, which have complex impacts on flora and fauna. Fire can also help to keep a savannah open and thus ensure that the insect-pest population remains low. As a result of interference with the species composition, however, insect pests may penetrate into hitherto unaffected areas and subsequently multiply here.

Theoretically speaking, breeding of livestock with particularly high resistance to a disease or vector (e.g. ticks) makes it possible to introduce a particular species into areas where it could not be kept in the past (Sutherst 1987). Indigenous

livestock, however, already possess a high degree of resistance. For example, West African zebu can acquire a certain "trypanotolerance" if they have lived in tsetse areas for a number of generations and are regularly exposed to the pathogen.

2.1.4 Epizootic-disease control

The purpose of epizootic-disease control measures is to prevent diseases from spreading. Such measures are necessary in connection with the export and import of animals and animal products. They comprise general control measures (e.g. export or import bans), compulsory vaccination, ring vaccination in the event of acute outbreaks of disease, quarantine measures, compulsory slaughtering of sick animals and directives governing disposal of the carcasses of animals that have died or been compulsorily slaughtered.

Compulsory vaccination is a means of keeping certain diseases effectively under control for a lengthy period of time.

Ring vaccination is often accompanied by quarantine measures. The resultant restriction of herd mobility may lead to overgrazing in some places, creating

tensions between sedentary and nomadic livestock owners. To ensure their acceptance, government quarantine measures should also take account of traditional practices that help to curb the spread of epizootic diseases.

Compulsory slaughtering is the most radical control measure, but is seldom used. It gives rise to severe financial losses for the farms affected and may oblige them to change their livestock management practices. For example, pastoralists may be forced to become less mobile if their herds fall below the critical size necessary for migration and this can create an increased risk of local overgrazing.

Disposing of dead animals by burning the carcasses creates unpleasant odours and pollutes the air. If wood is used, it also increases fuelwood requirements and thus women's workload wherever women are responsible for procuring wood (see also environmental brief Meat Processing).

Compulsory slaughtering is an emergency measure which prevents the spread of epizootic diseases and has beneficial effects on the health of both man and animal.

2.1.5 Zoonosis control

Through treatment of sick animals, prophylaxis, vector control and epizootic-disease control, veterinary services help to reduce the incidence of zoonoses and thus improve human health. Epizootic-disease control measures such as banning the keeping of dogs to curb the spread of echinococcosis and reduce the risk of rabies can restrict herding or make it difficult for nomads to guard their camps and thus have far-reaching socio-cultural implications. They may necessitate changes in livestock management practices and, by reducing mobility, can lead to overgrazing in certain areas.

2.2 Laboratory activities

2.2.1 Laboratory diagnostics

Preparation, transportation and handling of infected specimens in connection with laboratory work can give rise to environmental hazards. Improper handling and disposal of infectious specimens can endanger human health and contribute to the spread of disease.

In addition to the problems involved in disposing of non-reusable materials, there is also a risk that air, water and soil may be contaminated during

transportation, storage and disposal of chemicals and reagents. Incineration of specimens no longer needed likewise causes air pollution.

To protect the environment, it is essential that safety regulations be strictly observed and that glass and plastic containers, reagents, chemicals and the specimens examined be collected, recycled where appropriate and properly disposed of (see OECD 1983). Use of toxic chemicals can sometimes be reduced by selecting appropriate analytical methods.

2.2.2 Vaccine production

Apart from the usual environmental risks attaching to laboratory work, vaccine production also involves all the hazards that can arise when live pathogens are being handled.

The most essential environmental protection measures are strict compliance with safety regulations, improvement of safety facilities where necessary and appropriate disposal precautions.

2.2.3 Residue analysis

By bringing to light undesirable environmental impacts, residue analysis also helps to safeguard human health and can thus be seen as a form of environmental protection. Detailed residue analyses can often be conducted only in specially equipped laboratories (see also environmental brief Analysis, Diagnosis, Testing).

2.3 Artificial insemination and embryo transfer

Artificial insemination (AI) and embryo transfer (ET) are modern techniques for importing high-performance breeds (primarily cattle) into tropical and subtropical countries. Animals produced in this way and born in the importing country are better adapted to the environmental conditions there than those imported live. Artificial insemination is also a means of controlling the spread of venereal diseases.

AI and ET do not have any direct environmental impacts. By curbing the spread of venereal diseases they may contribute indirectly to improving livestock fertility and may thus lead to higher productivity and an increase in livestock numbers. The resultant effects on the environment depend on the prevailing husbandry system.

Importing of high-performance livestock calls for strict control of vectors and ectoparasites; it may also be necessary to step up chemoprophylactic measures (see Section 2.1 above). There is a danger that the contribution of AI and ET to raising animal production may be overestimated and existing production systems consequently neglected.

2.4 Food inspection

Veterinary control and inspection of foods of animal origin is intended to prevent human health being endangered by tainted or infected foods.

2.4.1 Meat inspection

Meat inspection has hitherto often been confined to large modern slaughterhouses. It is a prerequisite for the export of animal carcasses and thus contributes to improving the income of livestock dealers and producers.

Attempts to introduce and apply meat inspection regulations from other countries without creating the necessary infrastructure (monitoring services, analysis facilities) can lead to a loss of income. The activities of small village

slaughterhouses may be considerably restricted if they too are required to comply with such regulations and this can have an adverse effect on the rural population's meat supply. As women in some countries play an important role in slaughtering and meat marketing (particularly where small livestock are involved), such a development would have particularly serious consequences for the women's income and economic status.

However, meat inspection and proper disposal of products seized by the authorities prevent the spread of epizootic diseases and zoonoses. Hides contaminated with anthrax pathogens, for example, can be a highly dangerous source of infection for tanners.

2.4.2 Food hygiene

Milk hygiene plays a particularly important role in this field. Bacteriological monitoring is intended to prevent the spread of diseases such as tuberculosis and brucellosis, while analysis of milk composition helps to ensure high product quality. Milk testing and sales bans imposed as a result can have far-reaching social consequences if they extend to smallholdings which generally process only a few litres of milk a day and on which there is little danger that large quantities

of milk may be contaminated. Direct marketing of milk and other dairy produce is often a major source of income for women. Sour-milk products have the advantage that the souring process kills pathogenic germs. Boiling the milk to kill germs increases energy requirements.

Legislation on milk hygiene could conceivably be misused to force small-scale processing and marketing operations out of the milk production sector.

The possibility of health risks can be counteracted by advising and informing women about hygiene precautions to be taken during processing of dairy produce.

3. Notes on the analysis and evaluation of environmental impacts

The environmental impacts of traditional veterinary medicine have not yet been the subject of any summarising assessment. Use of traditional practices is generally confined to specific groups. Relevant references are contained in a number of annotated bibliographies (e.g. Mathias-Mundy and McCorkle 1989).

The OECD guidelines on sound laboratory practice provide pointers concerning the environmental impacts of laboratory testing and analysis. Information on this subject will also be found in the environmental brief Analysis, Diagnosis, Testing.

The environmental impacts of residue analysis are discussed in the relevant literature (e.g. Barke et al. 1983, DSA 1984, Rico 1986, Groklaus 1989).

4. Interaction with other sectors

Through treatment of disease, epizootic-disease control and vector control, the environmental impacts of veterinary measures are linked to those of animal production and fisheries. By monitoring hygiene in food production and processing, veterinary services contribute to environmental protection in other sectors (e.g. agro-industry, slaughterhouses and meat processing). Veterinary medicine is dependent on the pharmaceutical industry for its supply of modern drugs. Wastewater and solid waste disposal is of relevance to laboratory activities, which also have links with the chemical industry by virtue of the need for reagents and chemicals.

5. Summary assessment of environmental relevance

The principal tasks in the veterinary sector are disease control and food inspection. However, disease control measures and laboratory work may have adverse effects on health and the natural environment, either directly or indirectly. Regulations governing epizootic-disease control and food hygiene can interfere with the social structures forming the basis of the livestock owners' existence.

The traditional remedies used by livestock owners are often based on plant extracts, which play an particularly important role in the treatment of small animals.

Therapeutic and prophylactic measures may cause pathogens to develop resistance and can give rise to residues in food.

While traditional forms of treatment have few negative impacts on the environment, this is not true of modern drugs, particularly if they are used

improperly.

The activities of veterinary laboratories may give rise to water and air pollution; disposal of laboratory waste can cause contamination of air, water and soil.

Improved animal health is reflected in lower mortality and higher productivity, providing the producers with a more secure livelihood. However, consequent expansion of livestock husbandry can increase the danger of overgrazing if veterinary measures are not accompanied by improvements in the fodder supply and appropriate livestock management measures.

Epizootic-disease control, measures to curb the spread of zoonoses and monitoring of compliance with food hygiene regulations all have essentially positive effects on human health and the livestock owners' income. In some cases, however, incomes can be adversely affected. Imposition of excessively stringent standards for food hygiene can lead to the disappearance of small-scale slaughtering and milk-processing operations. Such a development could adversely affect the supply situation in rural areas and the income of those engaged in such activities, particularly women.

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32. Fisheries and aquaculture

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1. Scope

Activities for the purpose of obtaining food and other products from water bodies involve catching and gathering as well as farming and raising aquatic organisms (above all fish, crustaceans, molluscs and algae). Annual worldwide production in the fishery and aquaculture sector amounts to around 95 million tonnes.

The principal forms of activity are:

- capture fisheries
- aquaculture
- stocking and ranching

All three types of activity can be carried out in seawater, brackish water and fresh water and in both coastal and inland waters. Deep-sea operations primarily involve capture fishery, with aquaculture playing only a very small role. Stocking and ranching may include use of deep-sea areas in that fish released near the coast (e.g. salmon) may spend their growth phase in the open sea.

While inland and inshore fisheries and aquaculture are predominantly artisanal, deep-sea operations are primarily on an industrial scale where capture fisheries are concerned and exclusively so in the case of aquaculture.

Capture fisheries utilise natural stocks of aquatic organisms. Such activities influence the stocks not only by catching them but also by means of conservation measures (closed seasons, protected areas, catch quotas, use of selective gear). In aquaculture measures are taken to directly influence at least the growth stage and if possible also the reproductive stage, above all by controlling water quality (through the conditions under which the organisms are kept), nutrition (through

feeding and pond fertilising) and health (by means of prophylactic and therapeutic measures). The reproductive stage can be controlled by influencing maturation, egg and sperm production, hatching and larva raising. The characteristics of the organisms bred can be genetically influenced (e.g. by means of selection, crossing or genetic engineering).

Stocking and ranching combine aquaculture with fishery (culture-based capture fisheries). Natural or artificial bodies of water are stocked with young organisms which were hatched under supervision and spent the particularly critical early stages of their life cycle under controlled conditions. When the stocks created or augmented in this way reach the end of their growth stage, they are fished using normal capture-fishery techniques.

Between the "production" process - carried out under natural conditions (fisheries) or controlled conditions (aquaculture) - and consumption of the products there are a number of other stages which may likewise have environmental impacts: keeping fresh, processing, packing, transporting and marketing.

Fisheries and aquaculture can be divided into five main areas:

- artisanal small-scale fisheries
- small-scale aquaculture
- fisheries and aquaculture in artificial lakes
- fishery in the 200-mile exclusive economic zone
- fisheries and aquaculture in mangrove swamps

In the first two areas, emphasis must be on supporting low-income groups of the population and ensuring that appropriate technologies are applied. These two aspects likewise form the focus of attention in the use of artificial lakes for fisheries and aquaculture. By contrast, activities involving fishery in the 200-mile exclusive economic zone - predominantly at industrial scale - centre on preservation of resources and on managing and monitoring their use. Particular importance must be attached to environmental protection and resource conservation when the intention is to utilise mangrove swamps for fisheries and aquaculture, as measures involving the use of this fragile ecosystem should aim from the very outset to ensure that adverse environmental impacts are avoided altogether or kept to an absolute minimum.

2. Environmental impacts and protective measures

2.1 Artisanal small-scale fisheries

The actual fishing activities have the greatest bearing on the environment, as the long-term availability of the resources depends on the extent to which these activities are geared to the resource situation and to the conditions prevailing in the ecosystem fished. Through centuries of experience, traditional artisanal small-scale fisheries based in a specific location have made sure that they do not over-fish the available resources. Any attempt to increase production can jeopardise this well-established equilibrium.

It may nevertheless be possible to increase production without endangering the resources. Such an opportunity exists in cases where the stocks fished are utilised at a level below that guaranteeing optimum yield and sustainability. The same applies if fishing activities are extended to those components of the biocoenoses within the ecosystem that were previously utilised very little or not at all.

However, utilisation of additional species may be limited by the food relationships between various components of a biocoenosis. If the prey of a

predatory fish starts to be utilised in addition to the fish itself, the potential yield that can be derived from the predatory fish is automatically reduced, as the food supply has been curtailed. Since many such relationships exist, it is essential that they should be carefully reflected in the management models if it is intended to simultaneously utilise a variety of different organisms within a single ecosystem.

In management of fishery resources, a key role is played by the nature of the gear used as well as by when and where it is used. Modern fishing gear can be highly efficient (i.e. may jeopardise the existence of stocks if no restrictions are imposed on its use) and highly selective. Fishing gear is considered selective if it catches only particular species or size categories of organisms. Its selectivity can be determined by net mesh size, hook size, or the depth of water or depth zone in which it is used. The most important fishery management measures include closed seasons, protected areas, minimum mesh and hook sizes, limits on the number of sets of gear, boats or ships and on the times when they may be used, and stipulation of catch quotas and size categories for the organisms to be caught.

Stock management calls for a high level of training in fishery biology and adequate knowledge of fishery economics. Stock regulating measures should be

discussed, agreed upon and implemented by the local fishermen acting on a collective basis.

Apart from the need to conserve the resources themselves, it is also essential to protect their living environment against influences that could raise problems in the short or long term; to this end, the physical, chemical and biological condition of fishing areas must be monitored. Product quality depends on the chemical and biological conditions of the water and on the sanitary conditions prevailing ashore (village hygiene). The destructive effects of using wood resources for smoking fish can be curbed in two ways: by employing energy-saving kilns which permit more rational use of wood and by ensuring appropriate management of the forest resources concerned. The amount of wood required for boat-building can be reduced by replacing dugout canoes with boats made of planks and by using alternative construction materials.

Where it is likely that infrastructure for landing places used in artisanal fishery can be modified or removed only with difficulty, such facilities should not be constructed unless their necessity and expediency have been thoroughly reviewed. Concrete structures can also mar the aesthetic value of their surroundings (tourism).

2.2 Small-scale aquaculture

Aquaculture offers considerably greater options than capture fishery as regards both the type of organisms to be produced and the production sites. The natural stocks of organisms suitable for aquaculture can be most effectively conserved if aquaculture controls the entire life cycle, beginning and ending with the reproductive stage, and does so not just for one or two generations but on a long-term basis. As yet, however, this is possible only in the case of a few aquatic organisms. The only way of overcoming this problem is to promote applied basic research in the fields of reproductive physiology and reproductive ecology.

The production site should be chosen with the aim of conserving natural ecosystems and scarce water resources. The choice of the type of organism to be produced can contribute to conserving heavily used food resources if preference is given to species whose food requirements can be met by waste products or by-products from other sectors. Such products can either be fed directly to the fish or be used to fertilise the water and thereby promote the multiplication of food organisms (algae, microfauna). This could, for example, reduce demand for fish meal as a constituent of fish food. However, producers have a tendency to concentrate on expensive organisms (e.g. certain species of predatory fish) which

generally require food of extremely high quality.

Water quality within and downstream of an aquaculture facility is determined by management practices. Efforts must be made to ensure that as little leftover food as possible remains in the water and that the quantities of nutrients and pollutants washed out of the installation are kept to a minimum. The amount of leftover food can be minimised by gearing the quantities of food given and the frequency of feeding to the absorption capacity and appetite of the fish. If sizeable quantities of waste are nevertheless discharged (e.g. from intensively operated through-flow ponds), they can be caught in settling ponds and thus largely prevented from entering rivers and lakes.

Drugs for preventing and treating disease and for combating parasites should not be used in running water (through-flow ponds) for reasons of effectiveness and economy and should not be used at all in open systems (cages, pens), even if the fish then have to be transferred to special containers for treatment and are thereby exposed to stress situations.

The main way of saving energy in aquaculture is to obviate the necessity of pumping for the purpose of water renewal. Introducing new water benefits the

oxygen supply and helps to wash out wastes, besides compensating for evaporation and seepage losses. The extent of the necessary water replacement depends largely on the stocking density. Pumping energy can be saved wherever natural gradients can be used to create a water flow. Artesian springs are sometimes also available.

Considerable ecological advantages are offered by ponds in which wastes can be utilised by plants and microfauna which for their part are suitable as food for productive aquatic organisms. Such ponds can be fertilised by livestock (poultry, pigs) kept above or next to them. The profitability of this type of integrated aquaculture depends on the ecological appropriateness of the aquatic organisms kept, their popularity with consumers, the production costs and market prices. A role is also played by the way in which aquaculture is integrated into the overall production system, which usually involves other forms of production requiring labour. It is important, however, to know what constitutes the basis of the microfauna's food supply (there is a risk that pesticide residues could find their way into the food chain).

When setting up ponds in tropical countries, it is essential to bear in mind the risks originating from diseases whose pathogens spend at least one stage of their

life cycle in water or in aquatic organisms (malaria, schistosomiasis etc.).

Cage farming not only involves high feeding costs, but also gives rise to problems in procuring the necessary materials for making the cages, as nets, support rods and floats are expensive. Only in forested regions is the use of wood unlikely to present any problems.

Elimination of potential health risks attaching to consumption of aquaculture products must be given particular attention wherever human excrement and domestic wastewater are used for fertilising ponds. In wastewater aquaculture systems, the critical factors in this respect are the number of pond stages, the degree of dilution and the period for which the water is retained before it enters the fish ponds. Accurate management, along with regular checks on sanitary conditions and water quality, are essential in such cases.

2.3 Use of artificial lakes in fisheries and aquaculture

As use of artificial lakes involves a combination of fish farming and fishing (and can thus be placed in the category of "culture-based capture fisheries"), the environmental protection measures described in both 2.1 and 2.2 above are of

relevance in this connection. However, the fact that an artificial lake is a man-made entity creates a substantially different situation, both in limnological and ecological terms as well as from the sociological and economic viewpoints. Man-made lakes

differ from natural ones by virtue of their artificial nature, the fact that they are subject to continuous management to enable them to fulfil their primary purposes (drinking-water supplies, energy generation, irrigation), their initial biological "void" which - depending on the actual and to some extent random sequence of colonisation by flora and fauna - can offer scope for a variety of biological development possibilities, and last but not least the new options which this may offer in terms of fisheries and aquaculture. While an artificial lake thus allows man a considerable degree of freedom in shaping ecological conditions, it nevertheless confronts him with far-reaching social and economic problems when it comes to developing and establishing the ways in which it is to be used.

Two important principles should be observed when determining how a new artificial lake is to be used:

- Organisms that are foreign to the ecosystem and region concerned should be introduced only with strict observance of internationally recognised precautionary measures or not at all.

- No attempt should be made to regulate fishery activities until local traditions have been studied in detail; regulation measures should be realised in consultation with existing local fishermen and those willing to settle in the area.

When a new dam is being planned, consideration should be given to the various options for fisheries and aquaculture which the newly created lake will offer. Where appropriate, such aspects should be taken into account when deciding on dam design.

2.4 Fishery in the 200-mile exclusive economic zone

Optimum fishing of the 200-mile exclusive economic zone (EEZ) calls for use of advanced technology. This will inevitably lead to conflicts in the transition area between industrial deep-sea fishing and artisanal inshore fisheries unless depth conditions and coastline configuration create a natural division between the two. Such conflicts are often to the detriment of the available resources, causing them

to be over-exploited or even destroyed. They may also adversely affect the economic and social position of the artisanal inshore fishermen, who usually come off worst in such conflicts if their interests are not effectively safeguarded through government intervention.

While old-established, traditional fishing communities have developed fishing practices designed to ensure that resources are preserved in the long term, the technical potential of modern deep-sea fishing - which can totally exhaust resources within a short time - means that use of resources must be strictly limited and monitored. Minimum mesh and hook sizes must be laid down to make sure that the gear does not catch young organisms which are not yet mature enough to reproduce and thereby preserve the existence of the fish stocks. Such regulations can also reduce the pointless destruction of small food organisms caught in the nets together with the fish.

The only way to prevent trawls with "ploughing" structures from causing serious damage to entire communities of sea-bed organisms is to ban the use of such gear. Depending on local conditions (sea-bed conditions, reproductive cycle and migration of fish or other organisms), use of such nets must be banned either completely, or in specific areas or at certain times of year.

Complete bans must be imposed on catching certain types of organism while they are still going through their development phase in the "nursery areas". As such bans are often impossible to enforce, efforts are being made in many places to create artificial refuges - in the form of submerged concrete blocks, for example - to which fish and other aquatic organisms can retreat and from which they can repopulate areas which have been subject to adverse influences or whose stocks have been exhausted. However, the effectiveness and cost-benefit ratio of these "artificial reefs" are still the subject of considerable debate.

The death of numerous fish and large marine fauna (dolphins, turtles, birds etc.) in lost drift nets made of plastic that does not decompose in water can be prevented by using degradable thread to attach the net sections to the floats. The net sections would then collapse after a time and sink to the bottom. However, this method appears to be too complicated for general use and it is not known what damage the nets might cause on the sea bed.

Considerable problems are still posed by the question of what to do with the "by-catch" (of non-target species), in other words the organisms with little financial value that are caught together with the highly lucrative species (e.g. prawns or shrimps) constituting the intended catch. These organisms are large or

bulky enough to be retained by the net together with the main catch even if the minimum mesh sizes are adhered to. However, their market value is so low by comparison with that of the main catch that it is not worthwhile landing them, despite the fact that a considerable proportion of this "by-catch" would often be suitable for human consumption. If a worldwide solution to this problem could be found, for example by having the by-catch continuously collected by special boats at sea or by means of other methods, several million additional tonnes of fish would become available as food each year.

As is generally the case with motorised seagoing shipping, deep-sea fishing vessels' high consumption of fossil fuel necessitates special measures to dispose of residues on land. Environmental problems on land as a result of fishing stem primarily from industrial processing of the catch. Mandatory standards regarding disposal of solid wastes and wastewater must be observed; in some places such standards have still to be introduced. Some of the solid wastes can be made into fish meal, while valuable constituents of liquid waste can be recovered in the form of extracts and used as feed additives (cf. environmental briefs Inland Ports, Shipping on Inland Waterways, Wastewater Disposal and Solid Waste Disposal).

2.5 Use of mangrove swamps in fisheries and aquaculture

The traditional ways of using the flora and fauna in mangrove swamps can be viewed in the same light as artisanal small-scale fisheries in other areas: they take into account the regeneration capacity of the resources and are thus ecologically sound. However, this is not true of modern aquaculture on large fish farms whose construction necessitates complete clearance of the mangrove vegetation. One example of this type of operation is the large-scale raising of brackish-water prawns. As production of these much sought-after crustaceans can yield high profits, the potential suitability of mangrove swamps as sites for brackish-water ponds has given rise to dangerous pressure on these areas. Since mangrove areas are subject to the daily ebb and flow of the tide, the water has the necessary salt content and water replacement can be achieved at relatively little expense because the tidal cycle can be used to minimise the amount of energy required for pumping.

Efforts should be made to counter the pressure on the mangrove swamps in as realistic and flexible a manner as possible. The paramount principle should be that no form of use is to be permitted without thorough advance planning. The principal purpose of such planning is to completely rule out non-traditional use of areas which are irreplaceable as nature reserves, genetic resources, nursery

areas for important aquatic organisms or protective belts guarding against coastal erosion. Clearance of mangrove swamps for the purpose of aquaculture can also be prevented by making areas immediately upstream of the mangrove belt available for the creation of ponds. Provided that the installations are well-managed, the necessary pumping costs could be offset by earnings.

Where use of mangrove swamps appears unavoidable for economic reasons, activities should be concentrated in areas with clayey soils. In such areas the mangrove vegetation can easily re-establish itself if the ponds (or swamp-rice fields) are abandoned at a later date, whereas areas with sandy and peat soils will be nothing more than wasteland for a long time afterwards. Continuing efforts should also be made to find ways of utilising the natural productivity of suitable mangrove areas for semi-intensive small-scale aquaculture, without clearing them of all vegetation

and without major additional expenditure on feed or fertiliser. The success of such experiments will depend on whether or not it proves possible to keep costs down to a level ensuring that even low yields per unit of area offer attractive economic prospects.

3. Notes on the analysis and evaluation of environmental impacts

The environmental aspects of fisheries and aquaculture fall into five categories:

- **impacts on the natural environment which have adverse effects on aquatic organisms but which do not stem from either fisheries or aquaculture (pollution of water through disposal of wastes from industry, agriculture and households or caused by nutrients, pesticides and residues being washed out of soil on land; water-resources management measures); such impacts may affect both fisheries and aquaculture.**
- **influences on the existence and renewal of fish resources resulting from their use (such influences relate only to natural stocks and not to those maintained and controlled by man, i.e. aquaculture is affected only where it is dependent on young organisms from natural stocks).**
- **environmental impacts caused by fisheries and aquaculture (disturbance of ecological equilibrium, impairment of water quality etc.).**

- influences on use of resources (and thus on the resources themselves) caused by changes in the social and socio-economic situation of producers and consumers (e.g. as a result of population growth).
- effects of fishery and aquaculture activities on the social and socio-economic situation of producers and consumers (e.g. in the event of local overproduction without sufficient access to more distant markets).

Computer-aided simulations of both the ecological and economic situation, using a standard model, can help to ensure that natural fish resources are optimally utilised in a manner which preserves their capacity for renewal. Such models are essential for developing a reliable long-term utilisation strategy which takes into account the economic interests of both the fishermen and the country concerned without jeopardising in the long run the natural resources on which fishing depends.

There as yet exist no summarising overviews or evaluations of the serious impacts which various modern techniques can have on resources (use of explosives and pesticides, bottom trawling, use of drift nets etc.).

Considerable efforts are currently being devoted to studying and evaluating the

environmental impacts of aquaculture activities. In September 1990 the International Centre for Living Aquatic Resources Management (ICLARM) held a symposium on environment and aquaculture (results to be published in 1992).

4. Interaction with other sectors

Activities in the fisheries and aquaculture sector can be combined with agricultural production and with water resources development. The following are examples of the ways in which fisheries and aquaculture can be integrated with agricultural production:

- **combining fish farming (or artisanal fisheries) with plant production and animal husbandry in an agricultural production system without physical integration of the individual components**
- **combining fish farming in ponds with keeping of poultry, pigs or other livestock above the ponds**
- **fish farming in swamp-rice fields**

The following are examples of the ways in which fisheries and aquaculture can be combined with water resources development:

- **fishing in artificial lakes of all kinds (including those designed to provide drinking-water supplies)**
- **fish farming in small, shallow irrigation reservoirs**
- **fish fattening in large irrigation canals**
- **cage fish farming in adequately large and deep artificial lakes not used to provide drinking-water supplies**

(cf. environmental briefs Large-scale Hydraulic Engineering, Irrigation and Rural Hydraulic Engineering).

Fisheries and aquaculture also have extensive links with agriculture through the use of waste products, by-products and (in exceptional cases) main products of agriculture as food or fertiliser in aquaculture and through the use of fish meal in the production of livestock fodder (cf. environmental brief Livestock Farming).

Links with the forestry sector exist by virtue of the wood required for making boats and fishing gear, for preserving and processing fish by means of smoking

and for making cages. The close ecological links between forests and waters are of particularly far-reaching significance and must be taken into account in both forestry and fishery activities.

Fisheries and aquaculture also have links with the energy sector through the operation of boats, ships and sophisticated fishing gear, fishing ports, refrigeration plants and industrial processing facilities, technically complex aquaculture installations and vehicles for transporting people, equipment, supplies and products.

Attention has already been drawn in the text to links with other sectors.

5. Summary assessment of environmental relevance

Fisheries and aquaculture are dependent on the existence of an environment which is intact or at least not permanently damaged, but can themselves have negative effects on the environment and on resources. As fisheries rely on continuous natural renewal of fish resources, activities in this field must treat

these resources and their habitats with care.

Wherever resources have already been overfished and their habitats adversely affected by environmental changes, they must be rehabilitated if possible. Once fishing reaches a certain level of intensity, improved utilisation of catches is the only way of raising production. To this end, particular efforts should be made in the future to promote consumption of types of fish which are currently still unattractive from the commercial viewpoint and are simply used for making fish meal, and to ensure that fewer fish are lost as a result of spoilage.

Aquaculture is for the most part still a relatively new field of activity in the fishery sector. To promote its future development it requires tailor-made strategies which take particular account of the fact that most of the natural resources employed in aquaculture (water, land, feedstuffs; spawn in the case of most cultivated species) are already used for other purposes and can thus become sources of conflict. One of the most important strategic principles must therefore be to avoid such conflicts or resolve them with a minimum of adverse consequences in the ecological, economic and social spheres. This means, for example, that

- the impacts of aquaculture must initially be compared with those of other ways of utilising resources (e.g. mangrove forests as a means of preventing coastal erosion, tourism), with aquaculture activities then being designed as far as possible such that they complement use of water resources for other purposes;

- by-products or waste products that cannot be put to beneficial use elsewhere should be used as far as possible for feeding aquaculture organisms and fertilising the water. It is vital, however, that such products should be free of contamination (e.g. by pesticides).

Observance of the basic principles can be encouraged if the long-term advantages are demonstrated by effective examples and appropriate political and ecological conditions create a balanced combination of incentives and restrictions.

When involved in the development strategy and given appropriate training, women can play a key role in helping to prevent, reduce and eliminate environmental and health risks. Particular importance must be attached to awareness-raising measures that take religious considerations and cultural aspects into account.

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33. Agricultural engineering

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6. References

1. Scope

The fundamental components of agriculture are plant production and - based upon this - animal production. Agricultural machinery and implements are used by man for the purpose of influencing the natural process of plant and animal growth. Such mechanical aids can be divided into three categories on the basis of their energy source:

- hand-held implements
- animal-drawn implements
- motorised implements (with internal combustion engine or - less commonly - electric motor)

Agricultural engineering covers all aspects of using and manufacturing technical aids for agricultural production, the upstream and downstream sectors, and decentralised generation and use of energy in rural areas.

It is in plant production that agricultural engineering plays by far its most important role, although it is also becoming increasingly significant in livestock farming (intensive livestock husbandry). Mechanical aids are most commonly used in tillage and transportation, as well as in threshing and - where appropriate - for supplying water. As an area of project activity, agricultural engineering can thus be viewed in particular as an extension of the plant production sector; links frequently also exist with animal production, irrigation and agro-industry. The comments made in the relevant environmental briefs regarding objectives, impacts and protective measures apply by analogy.

2. Environmental impacts and protective measures

2.1 Man, ecosystem and agricultural engineering

2.1.1 Man and agricultural engineering

Agricultural operations are generally mechanised for reasons of labour efficiency, namely

- to raise per-capita productivity (worker performance) and
- to reduce the burden imposed by physical labour.

The changeover to a different source of power - i.e. from manual labour to animal traction to motorisation - brings major new technical and economic factors into play. This means that operation, maintenance and management must all meet correspondingly higher standards.

While the burden of heavy physical labour is reduced, work may subsequently become one-sided or monotonous. Animals or machines determine the pace of the work. Noise prevents communication and can adversely affect health, as can engine exhaust emissions.

Operators and other people can be endangered if machines get out of control. Moving parts (shafts, belts, rods) increase the accident risk.

Operation of machinery generally enjoys higher status than manual labour or handling of animals. Mechanisation can lead to changes in the division of labour and distribution of income, with "women's work" becoming "men's work" (seldom the reverse).

The way in which technical aids are used is generally the crucial factor determining whether they have positive or negative impacts. As motorised techniques tend to magnify errors, however, such methods can have considerably more serious negative effects than may result, for example, when hand-held implements are used.

It is particularly important that the right equipment be selected for a particular operation and that machinery and implements be used properly and at the right time. This can be achieved above all by training and advising the operators and by imposing legislative requirements (accident prevention, technical inspection etc.).

2.1.2 Ecosystem and agricultural engineering

As the degree of mechanisation increases, cropping areas and roads and tracks are geared to the demands of the machines and implements. Use of tractors and self-propelled machines such as combine harvesters - or indeed even the use of animal traction - calls for large cropping areas, which should be as free as possible of obstacles such as stones, trees and tree stumps.

Intercropping - i.e. simultaneous cultivation of several different crops in a single field - offers few opportunities for mechanisation and single-cropping systems therefore predominate. Following tillage, the surface of the ground remains unprotected for several weeks and may be exposed to the risk of erosion by wind and water. Broadcast sowing is replaced by row seeding; rows which follow the slope of the terrain can increase the danger of erosion by water. Roads and bridges, as well as irrigation and drainage channels, are often designed to meet the requirements of mechanisation. Ecologically valuable areas such as forests, hedges and fallow land are increasingly lost.

The spectrum of flora and fauna in a region may be diminished or altered; ecological diversity is reduced. An absence of windbreak vegetation in arable-farming areas increases the risk of erosion by wind.

Top priority must be given to promoting mechanisable land use systems which take both economic (including labour efficiency) and ecological aspects into account. Such production and farming systems have already been designed for certain regions (particularly in temperate climates) and their use is to be encouraged. Applied research and development work is still needed in other regions. It is not enough, however, to provide purely technical training and advice

on proper use of machinery and implements. A new awareness is required on the part of all concerned (from agricultural workers to decision-makers) if the inherent potential of mechanisation is to be utilised and risks are to be recognised and reduced.

It is important to preserve refuges, forests, hedges, wetlands and other niches for flora and fauna. Such areas do not hinder large-scale mechanised farming, as there are few labour-related advantages in having cropping areas larger than 20 hectares. Row seeding is essential in order to permit mechanical weed control techniques, for example, to be used instead of chemical methods.

2.2 Agricultural engineering in general

2.2.1 Energy sources, drive systems, fuels and lubricants

The principal sources of power are manual labour, animal traction and engines or motors. Wind and water power are used all over the world to drive stationary machines (mills and pumps).

In many countries, biomass (particularly wood, but also straw and dung) is the

major source of energy for cooking in rural areas (see also environmental brief Renewable Sources of Energy).

The demands of agriculture may sometimes compete with those of rural households. If draught animals are kept, land must be used for cultivating forage crops and is thus not available for growing food; use of dung as fuel deprives the cropping area of nutrients; both stationary and mobile engines (e.g. those of tractors) are still fuelled for the most part by non-renewable forms of energy, particularly petroleum products.

As such engines are not required to power vehicles travelling long distances, they emit only limited quantities of nitrogen oxides and carbon monoxide. Use of clean fuel and correct engine tuning can nevertheless help to minimise harmful emissions.

Where internal combustion engines are used (e.g. in tractors and water pumps), surface water may be contaminated by fuels and lubricants. The risk is particularly high in parking areas and workshop yards where fuel tanks are filled and oil changes performed.

The technical facilities used for transporting and storing fuels and lubricants are often in need of improvement. Tanks must be checked for leaks and contamination. Oil collectors for use during oil changes are to be provided and a used-oil processing system is to be set up. Negligence in handling fuels and lubricants (which can create fire hazards and lead to contamination of soil and water) can be reduced only by means of long-term training measures and appropriate technical facilities. Efficient governmental or private monitoring institutions (e.g. like Germany's water authorities and technical inspectorates (TV)) must be established.

Use of biodegradable oils is to be promoted. Where power saws (whose chains require a great deal of oil) are used in water conservation areas, for example, only vegetable-based lubricating oils (rape-seed oil) should be employed as is the case in Germany. This regulation is to be extended to cover hydraulic oils for vehicles operated in water conservation areas. It is recommended that use of such oils in agriculture also be encouraged.

2.2.2 Production of technical aids

Hand-held implements and simple animal-drawn implements are often made by

the family wishing to use them or by local craftsmen. Such production activities have few if any environmental impacts. The comments made in the environmental brief Mechanical Engineering apply in the case of industrially manufactured agricultural machinery and implements.

2.3 Specific aspects of plant production

2.3.1 Tillage

Loosening the soil with the aim of improving conditions for the crops plays a crucial part in arable farming. One purpose of turning the soil is to eliminate plants competing with the crop.

The extent to which the soil structure is changed depends on the form of tillage, which may involve

- **loosening the soil with hooks or tines,**
- **turning the soil with the plough, or**
- **crumbling and breaking up the soil with a powered rotary cultivator or harrow.**

If greater drive power becomes available, this may lead to selection of implements (e.g. rotary cultivator rather than plough) which modify the soil structure to a greater extent. In addition, less suitable (marginal) sites may be "put to the plough". Both of these steps increase the risk of soil degradation, which may involve reduction of pore volume, water absorption capacity and water storage capacity, the danger of puddling and crusting and a loss of organic matter. Crusting impedes water penetration and plant growth.

The optimum degree of soil moisture for tillage lies within narrow limits. If the soil is tilled when it is too wet it will be compacted, while tilling a soil which is too dry will result - depending on its clay content - in formation of clods or pulverisation. Compaction may assume sizeable dimensions if heavy tractors and implements are used.

Among other things, compaction of the soil has effects on plant growth, soil organisms and the availability and breakdown of plant nutrients and pesticides. On slopes, soil layers above the compacted horizon may slip.

Loosening of the soil and introduction of organic matter have positive impacts on the soil fauna. By contrast, compaction and puddling, frequent disturbance of the

soil by tillage and application of pesticides and fertilisers all adversely affect the development of soil organisms.

Measures for preventing soil erosion and compaction include the following in particular:

- The soil should if possible have permanent vegetation cover in the form of living crop plants (permanent cropping, intercropping, alley cropping) or dead plants (mulch).
- Crops should be sown directly into the remnants of the preceding crop (without the soil being turned).
- Crop residues should be left on the surface and should not be ploughed under.
- Coarse soil structures are to be created or preserved through appropriate crop rotation measures and use of suitable implements.
- Contour ridges or terraces are to be created on slopes. This may be a somewhat complicated operation; there may be no vehicle access to the land in question.
- Windbreaks are to be planted at right angles to the direction of the prevailing wind.

- Organic matter is to be preserved and increased if possible.
- The pressure to which the soil is subjected when vehicles are driven over it is to be reduced as far as possible by using small/light-weight tractors and machines or larger tyres.
- Where possible, the soil should be driven over and tilled only when the moisture content is optimum.
- Shallow and deep tillage implements are to be used alternately over the course of time.

Emphasis must be placed on promoting a willingness to abandon excessive exploitation of the soil in favour of sustainable, site-appropriate forms of cultivation.

2.3.2 Sowing/planting, crop tending and fertilising

Sowing and planting, which are performed after the soil has been tilled, are intended to create optimum conditions for the growth of the seed or young plant.

After tillage, the soil may be totally or partly without cover until the crops have

fully developed. It is thus exposed to the risks of erosion and to puddling as a result of heavy rainfall or severe evaporation.

With large cropping areas, mechanical aids are virtually essential for distributing chemical pesticides. Such equipment calls for highly skilled operators. Unsuitable, defective or incorrectly operated equipment can result in overdosage of fertilisers and pesticides, which will have negative effects on soil, plants and water as well as on the equipment users.

Application of highly concentrated liquid pesticides using the ULV (ultralow-volume) technique may lead to severe air pollution, with drift causing contamination over wide areas.

Pesticide users can be exposed to serious health hazards by touching or inhaling the chemical substances. It is often difficult to empty the containers completely and water used to rinse them out can contaminate surface water and drinking water. Pesticides and the equipment used to apply them are often stored improperly and are frequently kept in the same place as food for want of any other lockable rooms (see also the detailed remarks in the environmental brief Plant Protection).

Under unfavourable conditions, mechanical weed control measures (hoeing) can destroy the soil structure and encourage erosion; despite this fact, they should still be preferred to chemical methods.

Agricultural engineering can make a major contribution to ensuring that pesticides and fertilisers are used and applied correctly. Apart from selection of the right equipment, which is determined in part by the formulation of the agents used (e.g. powder or liquid), correct operation is equally important. If the time of application is appropriately chosen and economic-threshold concepts are used, quantities can be cut, drifting reduced and risks thereby minimised. Protective clothing, including face masks, is to be provided.

Under the climatic conditions prevailing in the tropics and subtropics, however, wearing of such clothing imposes considerable physical stress.

The stresses and risks for the equipment operators can be reduced to a large extent if the work is appropriately organised (e.g. operators proceed in the direction in which the wind is blowing).

2.3.3 Harvesting, threshing, processing, preservation, storage

The technical aids used in harvesting and threshing are intended to enable the work to be performed more easily and rapidly, besides minimising losses and risks. Harvesting and processing of "dry goods" (e.g. grain, burned-off sugar cane) can give rise to dust emissions which affect only a small area but are highly intensive. Such emissions affect people working and living in the vicinity, as well as animals. They can be reduced by taking technical measures at their source or their effects mitigated through the wearing of face masks and protective clothing.

Threshing and processing may yield by-products (glumes, hulls etc.). However, the quantities occurring at farm level do not constitute a serious environmental hazard, since the farm can generally utilise such products itself.

When crops are harvested, various substances are removed from the natural cycling systems on the site concerned. Efforts should be made to ensure that at least the by-products are returned to the soil either directly, after use for other purposes (e.g. as livestock fodder) or after composting.

Technical measures for preserving and storing produce at farm level seldom have any environmental impacts, unless chemicals are used. Crop drying calls for an energy supply, however, and in certain cases this may lead to over-use of local

forest resources. Efforts to alleviate this problem should focus on ways of reducing energy consumption (heat sources).

2.3.4 Supplying and distributing water

To supplement the environmental brief Irrigation, attention must be drawn here to a number of important interrelationships and areas of overlap between these two sectors.

The water application and distribution system (gravity-flow method with open channels, pressure method with pipes or hoses) has a considerable influence on mechanisation:

- **Channels determine the field size and bridges are needed to cross them.**
- **Small embankments and ditches in the field are damaged when driven over.**
- **Pipes have to be removed before a field can be tilled or urgent plant protection measures carried out.**

2.4 Aspects of animal production

Pasture farming has always been the traditional form of livestock husbandry. The use of technical aids is confined to protective and security measures (pens etc.); the same applies to the keeping of small animals (e.g. poultry, rabbits, bees). It is not until livestock farming is intensified, with livestock kept in confinement, that technical aids become increasingly important. In industrialised countries where intensive animal husbandry is practised (particularly in Europe), technical equipment has come to play just as vital a role in livestock farming as it does in crop growing.

In poorly ventilated livestock housing, heat, dust and gases - particularly ammonia - can create stresses for both man and animal.

Sizeable quantities of ammonia can escape into the air when animal excrement is stored and applied to fields as manure. In industrialised countries, ammonia is one of the principal factors causing the gradual death of the forests in regions where intensive livestock husbandry is practised. One effective countermeasure is to make sure that solid or liquid manure is immediately worked into the soil.

Improper storage and spreading of animal manure can lead to over-fertilising (eutrophication) of both surface water and groundwater.

Protective measures must often focus first of all on bringing about changes in awareness, for only when this has been achieved can technical measures contribute to reducing negative environmental impacts. Animal excrement must be regarded and treated as a valuable fertiliser and not as waste. It is also important that this fertiliser be spread over the cropping area precisely in line with the plants' nutrient requirements. Only if such measures can be realised will it be possible to develop intensive livestock farming methods that are environmentally sound in the long term.

3. Notes on the analysis and evaluation of environmental impacts

Among the negative consequences of cultivation - magnified by use of mechanical aids - it is erosion that has by far the greatest significance worldwide. While there are numerous ways of reducing erosion (e.g. crop-growing measures such as mulching, technical measures such as terracing and planting of windbreaks),

standards for evaluating the effect of erosion are largely confined to criteria for recording and assessing the removal of soil. Specific cultivation bans or requirements are occasionally imposed in the catchment areas of reservoirs particularly at risk from sediment.

Manufacturers of tractors and agricultural machinery in industrialised countries are called upon to fulfil widely varying national environmental requirements. These include

- **standards and guidelines on design and durability;**
- **provision of safety devices, protective circuits etc., particularly for motorised vehicles and machines;**
- **provision of special equipment if the vehicles use public roads (danger to other road users);**
- **emission standards (exhaust emissions, noise).**

Institutions performing official functions, such as agricultural-machinery testing stations, carry out type approval testing whose results are binding on manufacturers. Compliance with requirements is relatively easy to monitor.

It is far more difficult to ensure that regulations are observed by users. Safety devices may be removed, protective clothing and masks not worn or emission standards, speed limits and the like disregarded.

4. Interaction with other sectors

Agricultural engineering is closely linked to the following sectors:

- Plant production: agricultural engineering constitutes an extension of this sector in virtually every respect
- Plant protection: mechanical methods, application techniques
- Livestock farming: use of animal traction, intensive animal husbandry (still on only a small scale in developing countries, but extremely widespread in industrialised nations), livestock farming practices
- Irrigation: particularly supply, application and distribution of water, gravity-flow and pressure irrigation methods (sprinkling, drop irrigation)
- Agro-industry: primary products ("large-area products" such as grain and sugar), use of wastes

- **Rural hydraulic engineering: correlation with plot size**
- **Renewable sources of energy (biomass)**
- **Mechanical engineering**
- **Mills handling cereal crops**

5. Summary assessment of environmental relevance

The fundamental elements of agriculture are plant production and - based on this - livestock farming. Man uses technical aids in order to influence the production systems and enhance their productivity. Agricultural engineering is an integral component of these systems; its environmental impacts cannot be considered without reference to those of plant and animal production. Mechanical aids are most commonly used in tillage and transportation, with effects above all on soil, plants and man.

Among the negative consequences of cultivation, it is erosion that has the greatest significance worldwide. All other effects resulting from the use of technical aids in agriculture remain limited to the locality or at most the region

concerned.

Improper storage and application of pesticides, mineral fertilisers and animal excrement can lead to contamination and/or over-fertilising (eutrophication) of both surface water and groundwater.

Most agricultural operations are mechanised for reasons of labour efficiency. Machines and implements call for a high degree of expertise in operation, maintenance and management if their use is not to have negative impacts. In many countries, responsibility for certain types of work passes from women to men.

Intensification of agriculture with the aid of agricultural engineering can lead to a change or reduction in the spectrum of flora and fauna found in a region.

The most important protective measures comprise

- provision of training and advice, and
- development and introduction of mechanisable land-use systems which take both economic (including labour efficiency) and ecological

aspects into account.

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<u>Examples of German regulations and standards:</u>

BBA: Regulations laid down by the Biologische Bundesanstalt (BBA - German Federal Biological Research Centre for Agriculture and Forestry) concerning use of pesticides.

Berufsgenossenschaften: Accident prevention regulations (Unfallverhtungsvorschriften) laid down by agricultural and industrial employers' liability insurance associations ("Berufsgenossenschaften").

DIN: German Standards and regulations on construction and design.

STVZO: Provisions of the German road transport licensing regulations.

TA Lrm: Technical Instructions on Noise Abatement, 1968/1974.

TA Luft: Technical Instructions on Air Quality Control. First general administrative regulation accompanying the Federal Immission Control Act,

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