Foreword

Soil, the most basic natural resource, is finite and fragile. It may take thousands of years to produce a few centimetres of fertile topsoil. Only 11% of the earth's land area of 13.4 X 10^9 ha is currently cultivated. With rapidly increasing population, especially in tropical regions, the arable land per caput is rapidly decreasing. Densely populated Asia, with 75% of the earth's population, has little additional land to bring under cultivation. Most of the land in Africa and Latin America that can be brought under cultivation is located within fragile and ecologically sensitive regions, for example tropical rainforest, acid savannah, drought-prone sahel, steepland of the Andes. Potentially productive agricultural land is either inaccessible, too steep, too shallow, too wet or too dry.

Soil degradation is widespread, particularly in the tropics, where it is a major economic and ecological constraint. It leads to poor yields, poor standards of living, and contributes to hunger and malnutrition. The ecological consequences of soil degradation include pollution of wind and water by sediment and dust, and eutrophication and contamination of natural waters by sediment-borne pollutants. Processes of soil degradation most prevalent in the tropics include soil erosion and desertification, compaction and hard-setting, salt and water imbalance in the root zone, biological degradation including reduction in soil organic matter content, fertility depletion, and chemical degradation including leaching and acidification.

Tillage, mechanical soil manipulation for seedbed preparation, affects the rate and trend of soil degradation. In addition to establishing the seed-soil contact, tillage is used to alleviate soil compaction and so improve infiltration capacity; to dispose of pathogen-infested crop residue; to incorporate fertilizer into the root zone, and to eradicate weeds. The kind of tillage and its frequency depend on the soil and its related constraints to crop production. A wide range of tillage implements has been developed to alleviate unfavourable soil conditions. Manual or animal driven tillage tools are widely used in small-scale agriculture, whereas motorized equipment is used in large-scale commercial or semi-commercial agriculture.

The term "mode" refers to the type of tillage whether primary, secondary or tertiary based on tools for soil inversion, loosening, levelling, mixing or pulverizing. Similarly, the term "means" refers to the source of power and the type of machinery for tillage. Both mode and means of tillage have changed drastically since industrialization in the 19th century.

Equipment has become larger and faster, so the risks of soil and environmental degradation have drastically increased. Recognition of the need to protect bare soil from soil erosion and erosion-induced degradation has led to the development of a wide range of practices involving the reduction of the intensity and frequency of tillage and the practice of leaving some crop residue or other biomass on the soil surface as a protective barrier against erosion. Reduced cultivation, an integral part of conservation tillage, has been widely adopted since the early 1950s.

The widely recognized risks of soil erosion and environmental degradation in the tropics are only partly due to fragility of the soils. Their susceptibility to degradative processes can be accentuated by mechanical soil distur-

bance. The harshness of tropical climates (high rainfall intensity and excessive energy load of rains, and extremes of temperatures) is another important factor responsible for soil degradation. Furthermore, the loss of nutrient-rich tosoil has more marked effects on crop yield, and productivity in low-input subsistence farming than in science-based semi-commercial or commercial agriculture. Tillage systems in the tropics are generally designed to lower soil temperatures and conserve soil moisture, in contrast to practice in temperate regions where agriculturalists attempt to drain excess water from the root zone during early spring and so raise soil temperatures.

The objectives of this *Bulletin* are to collate up-to-date information on soil tillage requirements for soils in the tropics; to assess the impacts of different modes and means of tillage on the soil and the environment and on crop productivity; and outline criteria for developing environmentally-friendly and economically-viable tillage techniques for sustainable use of soil and water resources. The question "Is tillage necessary?" is addressed to explore viable alternatives to mechanical soil disturbance. The question "How much cultivation, how often, and with what equipment?" is considered in relation to the short-term and long-term consequences for soil and environmental quality, with special reference to accelerated erosion, water pollution and emission of greenhouse gases.

The *Bulletin* is written for field staff, extension agents, policy-makers, project managers and researchers interested in tillage requirements and soil surface management for sustained crop production. While the technical terminology used is simplified and explained to facilitate its use by generalists, the scientific content and references quoted address the needs of active researchers.

An attempt is made to address the concern of research scientists, decision-makers and planners about the wide-spread problem of soil and environmental degradation. Why do soils of the tropics degrade so rapidly with intensive cultivation? How can this degradation be stopped without jeopardizing productivity? How can the productivity of degraded soils be restored? How can the labour-constraints of resource-poor farmers be addressed and their facility augmented to increase the land area under production? How can the drudgery of the farming practices in the tropics be alleviated and quality of life for the farming community be improved? How can subsistence farming be transformed into semi-commercial or commercial agriculture? These important questions require a critical and an objective approach.