Sustainable Agricultural Productivity

Definitions, Theories & Lenses

Input for Discussion

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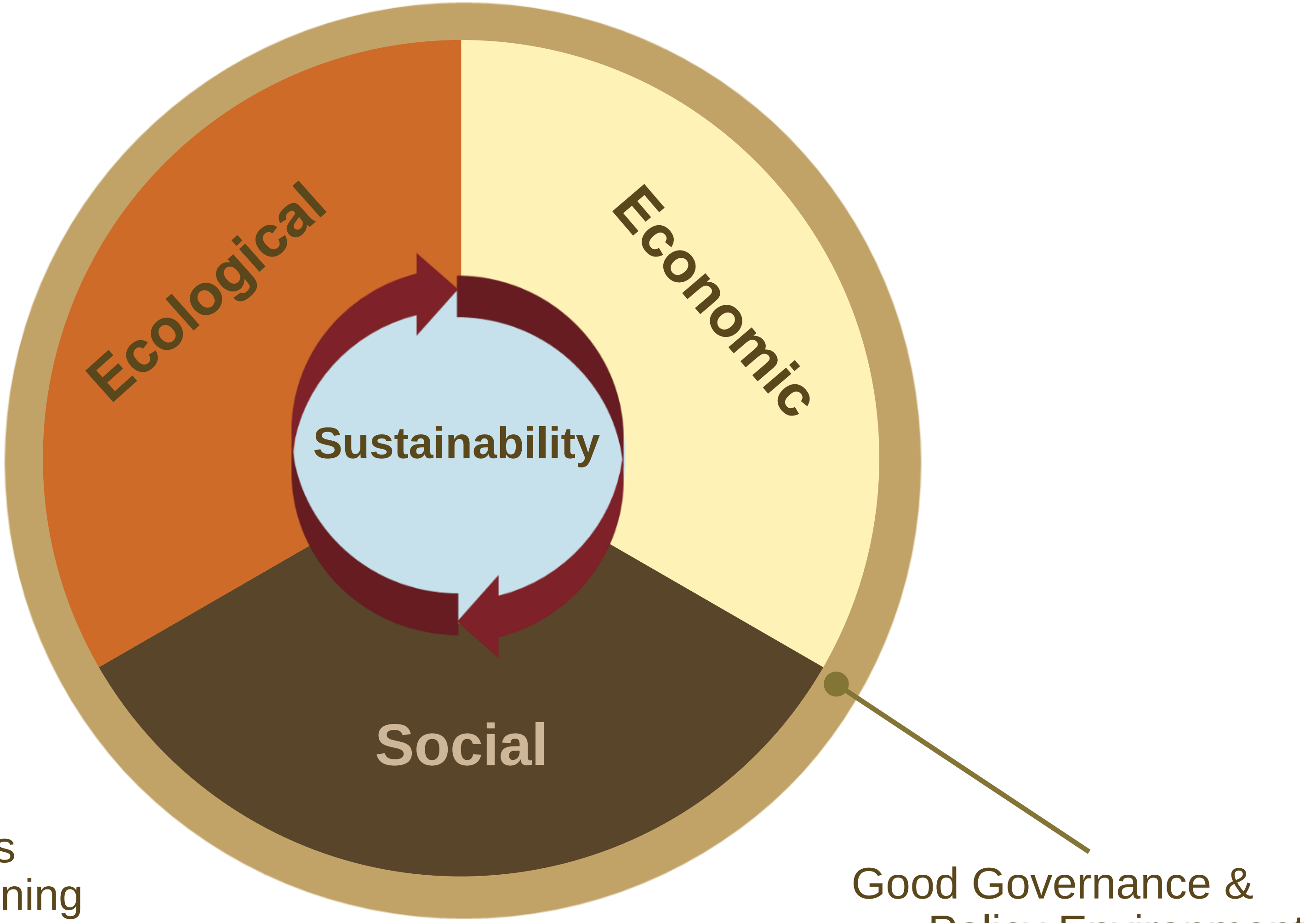
Overview

Sustainable Agricultural Productivity



= systems strengthening

Alignment with Existing Frameworks

Ecological Sustainability →

- Sustainable Agriculture
- CAADP Pillar 1
- MDG 7
- Millennium Ecosystem Assessment Framework

Sustainable Social Development →

- Pro-poor Development
- Sustainable Livelihoods
- CAADP Pillars 2 & 3
- MDG 1
- IFAD objectives
- Human Development Indicators

Economic Sustainability →

- CAADP Pillar 2
- MDG 1
- Private Sector Strengthening
- Public-Private Partnerships
- Value Chain & Systems Strengthening

Components of Ecological Sustainability

Elements	Goals	Sample Measures
Soil health	Environmental health	% of land with eroded soil
Water quality & availability	Sustainable land use	Ground & surface water consumption
Air quality	Crop & animal diversification	Metal & chemical pollutants and residue
Pests	Ecological resilience & biodiversity	Abundance of wild species
Plant genetic resources		CO_2 emissions
Energy use		Length of fallow
Human & animal health		

Components of Sustainable Social Development

Elements

- Income
- Nutrition
- Market access
- Access to education, information, technology, & financial services
- Household production strategies
- Gender

Goals

- Social & economic empowerment
- Gender equity
- Pro-poor growth
- Reduced hunger
- More equitable access to markets
- Asset building
- Income diversification

Sample Measures

- Share of the poorest quintile in national income
- Gender ratio in education & income
- Length of the lean period
- Proportion of population malnourished
- Child health & nutrition measures
- Poverty gap ratio

Components of Economic Sustainability

Elements	Goals	Sample Measures
Agricultural Productivity	Increased productivity of inputs	Agriculture value added
Input, output & labor markets	Growth in agricultural value added	Partial factor productivity in inputs
Infrastructure & transport	Increased on-farm income	Total and multi-factor productivity
Food prices	Pro-poor value chain linkages	Private sector participation
Rural-urban linkages	Well functioning product & factor markets	Food price level & volatility
Gender (especially female-headed households)		

The Case for Agricultural Productivity

- Global grain demand is projected to double by 2050.
- Agricultural practices determine both food production and environmental quality.
- Agriculture employs more people and uses more land and water than any other human activity.
- The impact of agricultural production on ecosystems and human welfare depends on the decisions made by more than 2 billion people whose livelihoods depend directly on crops, livestock, fisheries or forests.

To achieve sustainable agricultural productivity:

Crop and livestock production must increase without an increase in the negative environmental impacts associated with agriculture, which implies large increases in the efficiency of input use

Evidence for Productivity Growth through Sustainable Agriculture

Table 3. Summary of adoption and impact of agricultural sustainability technologies and practices on 286 projects in 57 countries.

FAO farm system category[a]	no. of farmers adopting	no. of hectares under sustainable agriculture	average % increase in crop yields[b]
smallholder irrigated	177 287	357 940	129.8 (±21.5)
wetland rice	8 711 236	7 007 564	22.3 (±2.8)
smallholder rainfed humid	1 704 958	1 081 071	102.2 (±9.0)
smallholder rainfed highland	401 699	725 535	107.3 (±14.7)
smallholder rainfed dry/cold	604 804	737 896	99.2 (±12.5)
dualistic mixed	537 311	26 846 750	76.5 (±12.6)
coastal artisanal	220 000	160 000	62.0 (±20.0)
urban-based and kitchen garden	207 479	36 147	146.0 (±32.9)
all projects	12 564 774	36 952 903	79.2 (±4.5)

[a] Farm categories from Dixon *et al.* (2001).
[b] Yield data from 360 crop-project combinations; reported as % increase (thus a 100% increase is a doubling of yields). Standard errors in brackets.

Pretty, 2008 based on data from Pretty et al, 2006

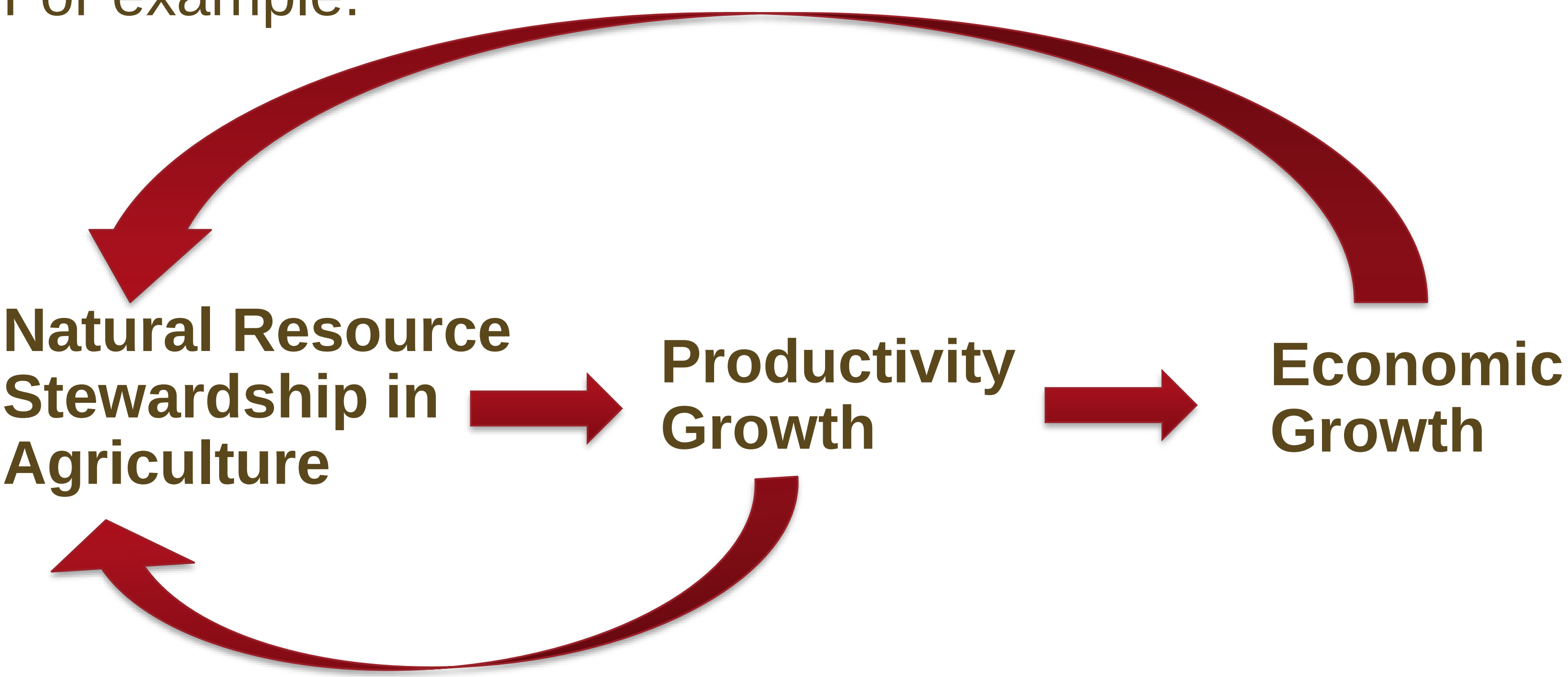
Agricultural sustainability technologies include: integrated pest management, integrated nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting, and livestock integration

% Change = change from before implementing a sustainable technology project to after, metastudy of individual intervention studies

Key Linkages

Conceptualizations of sustainability include multiple influences and feedback loops between activities, sectors and outcomes, resisting a simple depiction.

For example:



Key Linkages

- **Agricultural sustainability can improve productivity**
  - **Best farmland is already in use so further area expansion would occur on marginal land that is:**
    - Unlikely to sustain high yields
    - Vulnerable to degradation
  - **Overcoming current resource constraints requires greater nutrient-use efficiency through better matching of nutrient supply and plant demand**
- **Productivity growth can improve environmental quality**
  - Increasing production intensity decreases reliance on extensive productivity growth
- **Improved incentives can lead to better management of natural capital**
  - Can increase production (output) and economic growth

Economic Definitions of Productivity

Economic Definitions of Productivity

- Partial factor productivity
- Total factor productivity
- Total social factor productivity
- Multifactor productivity measures

Partial Factor Productivity Measures

Definition:

- Value of output, or index of outputs, per value of one input
- Average productivity of a single factor of production

Examples:

- Crop yields
- Land productivity
- Labor productivity
- Fertilizer efficiency

Limits to PFP Measures

- **PFP is easier to calculate than Total Factor Productivity (TFP), but**

- **Hard to draw clear policy recommendations based on PFP alone:**
  - **As use of one input (e.g. fertilizer) increases, average productivity of that factor will decline, even as yields increase**
  - **PFP of one factor is influenced by use of other inputs.**
  - **Input use is also affected by relative factor prices, in which case a decline in PFP may not be cause for concern**
  - **The implicit costs of “owned” factors (such as using one’s own labor or land) are often undervalued by not including the opportunity cost of not earning wages or renting the land.**

Total Factor Productivity (TFP)

Definition:

- The ratio of aggregate output to aggregate input
- In economic terms, TFP measures the average product of all inputs

Measurement:

- TFP is measured by developing indices of output and inputs
- Inputs include factors of production
  - Land (agricultural land, natural resources)
  - Labor (human capital, livestock)
  - Capital (the means of production including machinery, tools and fertilizer)

Limitations to TFP

- **TFP is essentially a 'residual'**
- **TFP is a theoretical concept – real world measures cannot capture all relevant outputs and inputs. In particular,**
  - TFP measurements depend heavily on quality of input measurements
    - Input data are very weak for developing countries
    - Difficult to adjust for quality of inputs
    - Revenue and factor shares are fixed
- **It is difficult to determine causes of change in TFP, which could result from**
    - Changes in macroeconomic conditions
    - Degradation of resource base

Total Social Factor Productivity (TSFP)

Broadens TFP measures to include:

- **Non-market inputs and outputs**
  - **Soil erosion, soil fertility, groundwater depletion, cost of environmental regulation and abatement**
- **Market and non-market inputs valued at long-term social prices**

Challenges to TSFP

- Pricing inputs at social costs does not correctly reflect the farmers profit maximization decision
- Social prices are rarely available or uncontested
- A better approach might be to improve productivity and resource quality measurement, then examine their relationship

Multi-factor Productivity (MFP)

MFP is the 'real world' approximation to TFP

The challenge:

- How to 'add up' heterogeneous inputs and outputs to create a meaningful measures?
- Which index to use? (Laspeyres, Paasche, Malmquist, etc.)

- Do we measure indexes of quantities (a 'primal' index) or indexes of prices (a 'dual' index)?
  - These are the same only under perfect competition and constant returns to scale

Agricultural Productivity

World Bank Agricultural Productivity Measure:

Agricultural value added per hectare of agricultural land where:

(1) value added measures the output of the agricultural sector less the value of intermediate inputs;
(2) agriculture comprises value added from forestry, hunting, and fishing as well as cultivation of crops and livestock; and
(3) agricultural land is the sum of arable land, permanent cropland and permanent pasture.

Other Measures of Agricultural Productivity and Food Security

- Crop yields per area
- Gaps in actual farm yields vs. potential yields
  - Potential yields determined by research station or demonstration plot yields
- Yield variability over time or over conditions
- Value of agricultural output per agricultural household
- Number of months of food stock on hand
- Volume and value of crop storage losses

Data limitations to economic measures

- Most require accurate and longitudinal data
- Crop yields are affected by multiple external factors (i.e. rainfall)
- Requires either a control group or accurate environmental data
- Often rely on farmer-reported data, which may be unreliable

Conceptual limitations to economic measures of productivity

- Current measures often do not connect agricultural productivity to hunger
- Measures using social prices do not reflect the decisions farmers actually make
- Current approaches do not fully incorporate ecosystem services provided by the environment

Incorporating Hunger into Productivity Measures

- **Alternative expressions could use energy or caloric measures in the denominator, rather than yields:**
  - Household labor input per nutritional (caloric) value of outputs
    - Labor inputs could be disaggregated by gender and age. This would focus attention on possibly counter-productive interventions that increase agricultural yield but increase labor/caloric outputs.
  - Units of animal fodder per caloric value of meat or milk output from livestock
    - This would focus attention on the environmental efficiency of livestock versus other types of agricultural options (crops, aquaculture) to reduce hunger and nutrition

Incorporating Sustainability into Productivity Measures

Defining Sustainability Draws from a Wide Body of Interdisciplinary Work

- There is limited consensus about how to define and operationalize 'sustainability'
- Common framework components include:
  - **Sustainable development**
    - ◊ Economic growth
    - ◊ Distributional equity
    - ◊ Natural capital and environmental resources
    - ◊ Poverty reduction
    - ◊ Institutional capacity
  - **Sustainable productivity (economic literature):**
    - ◊ Economic growth
    - ◊ New productivity models
  - **Sustainable agriculture & agricultural sustainability**
    - ◊ Ecological sustainability
    - ◊ Food security

These frameworks are all built around the idea of interconnected systems, complicating attempts to distinguish between component parts.

Sustainable Development

Our Common Future
The Brundtland Commission Report

- **This report was the first to use the term “sustainable development” and the following remains the widely accepted definition:**

> “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

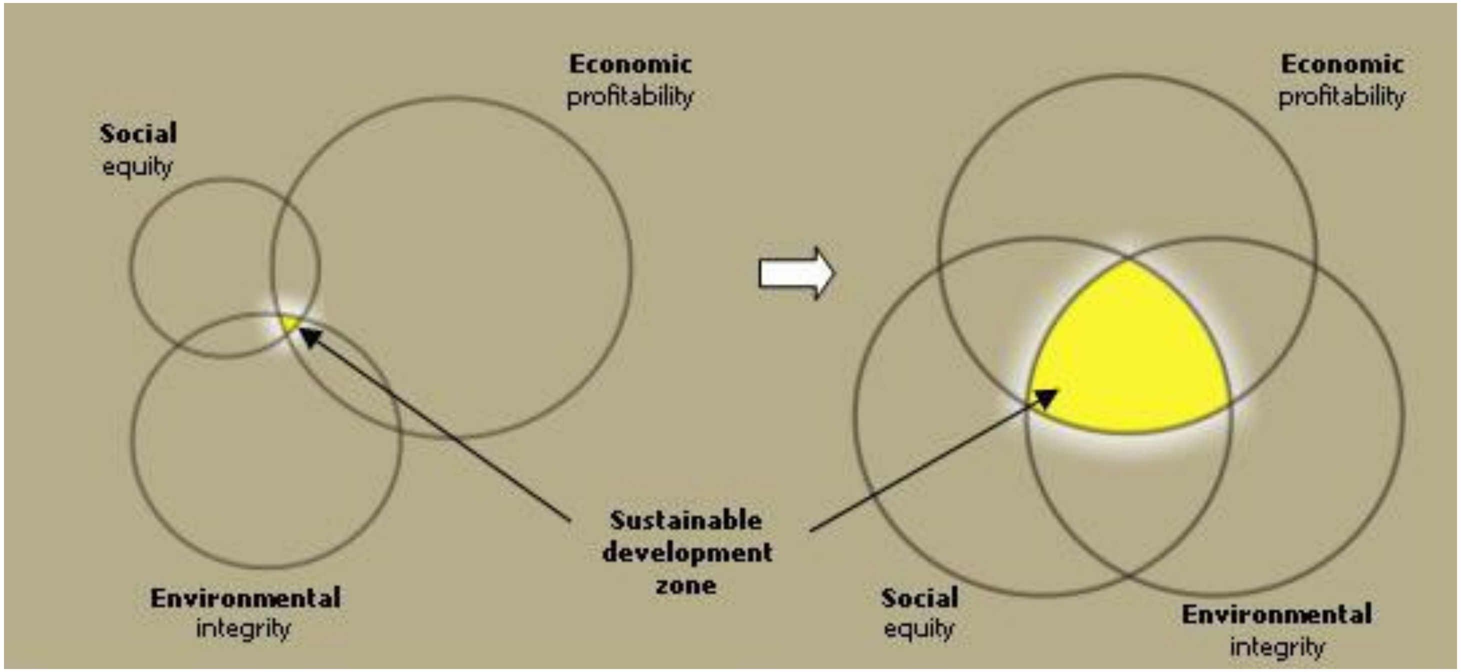
World Commission on Environment and Development, 1987

Sustainable Development

- **The sustainable development paradigm contains the following three pillars common across most frameworks:**
  - **Economic development**
  - **Ecological (environmental) sustainability**
  - **Sustainable social development**
- **Some frameworks stress additional components (governance, institutions, distributional equity)**

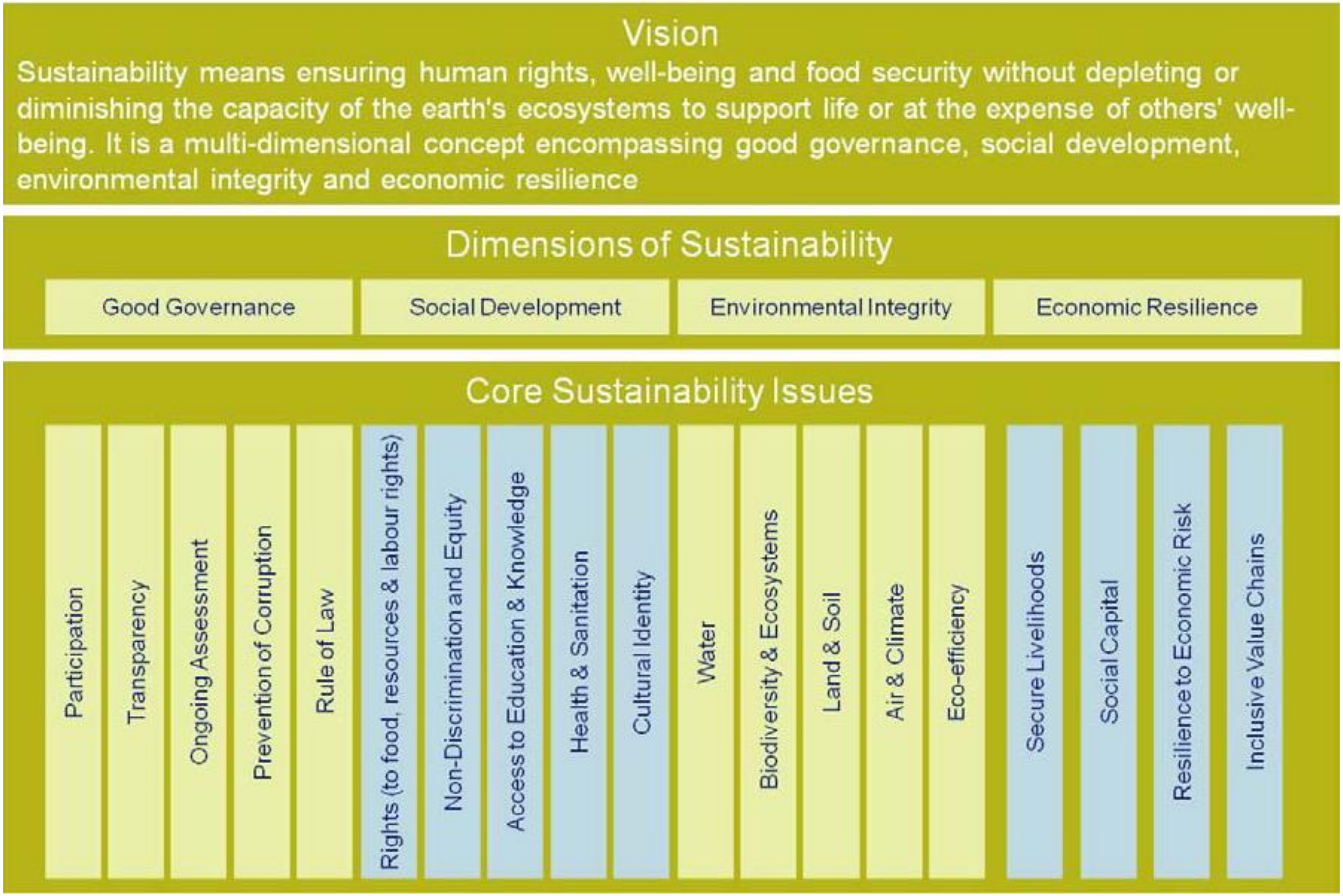
Sustainable Development

Convergence of the three pillars of sustainability represents an increased sustainable development zone.



Source: Government of Quebec

FAO and ISEAL Sustainability Framework



Economic Sustainability

- **An economy is *weakly sustainable* if it can maintain its aggregate capital stock (its productive base)**
  - This sustainability condition includes human capital
  - Implicitly assumes that manmade physical capital is an equal substitute for natural capital (and can compensate for depreciation of natural capital)
- **An economy is *strongly sustainable* if its natural capital stock is held constant or increases**
  - An even strong definition: ‘critical components’ of natural capital must be maintained, where
    - ◊ **Critical components** include: endangered plant and animal species, essential ecosystem functions, and other unique phenomena of nature

Sustainable Productivity

- **Productivity growth is tied to technical change, and both are heavily influenced by investments in research and development**
  - Some argue that in the case of chronically malnourished populations, increasing consumption contributes more to productivity growth than investment

- **Assessing the sustainability of productivity growth requires adjusting accounting methods to include ecological components and social pricing**

Sustainable Productivity

- **Sustainable Productivity can be assessed by total factor productivity (TFP) and its applied approximation, multifactor productivity (MFP)**
  - **Estimated productivity growth can be decomposed into three components:**
    - **“Pure” technical change (new technology)**
      - ◊ Shifts production possibilities frontier to a new level of technology
    - **Scale effects (efficiency gains through exploiting economies of scale)**
    - **Improvements in the degree of technical efficiency (using existing technologies to increase efficiency)**
      - ◊ This results in a movement closer to the economy’s production possibilities frontier, without shifting the production possibilities frontier

Limits to Current Productivity Measures

From a TFP perspective, a sustainable system has a non-negative trend in TFP over a given period

- Implies output is increasing just as fast as inputs

But TFP does not account for non-market outputs and inputs such as resource degradation and pollution

- Therefore changes in TFP may not reflect changes in the resource base

Defining Sustainable Agriculture

- **We define sustainable agriculture as practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered.**
  - **(Tilman et al, 2002)**

Key challenge: how to incorporate and value costs and benefits of agricultural practices to the environment and to human well-being

Sustainable Agriculture Measurement

- **Potential methodology for incorporating environmental inputs into productivity measures:**
  - **Graham (2009) environmentally sensitive farm-level productivity measure**
    - Agricultural output requires the use of both private and environmental (public) inputs
    - Traditional performance measures (financial inputs and marketed output) can be extended to include all inputs through a systems analysis of performance
      - ◊ Integrating biophysical and economic inputs into the one production model enables a more comprehensive analysis and enhances the development of a sustainable agricultural system

Another Measure of Sustainable Productivity: Genuine Investment

- **Emerging methodology attempts to measure the sustainability of productivity growth based on the level of an economy's *genuine investment* (Veeman, 2008)**
  - Genuine investment defined as a change in the productive base including all investments and disinvestments in manufactured capital, human capital, natural capital and the knowledge base
    - ◊ **Sustainable productivity requires that genuine investment be non-negative**

Most agree that this methodology is still crude and requires research and refinement

Sustainable Production Requires Adequate Risk Management

- **Adverse shocks (e.g. weather), and inefficient risk management strategies can decrease productivity**
  - **Self-insurance and risk-sharing are common risk management strategies for the poor in rural areas**
    - This can lead to an inefficient allocation of resources and thus lower productivity
  - **Inability to manage variation in production can have severe welfare consequences for the very poor**
  - **Interventions working through food, labor or credit markets to protect the poor from risk and uncertainty have proved expensive and unsustainable in the past**
    - Proposed sustainable approaches to social protection address both production and consumption (Devereux, 2001)

Ecological Perspectives on Sustainability : Resilience

Resilience can be understood as:

- **The speed of return to equilibrium following perturbation (Pimm, 1984)**

- **The size of disturbance needed to dislodge a system from a stable equilibrium (Holling, 1973)**

- **From an ecological perspective, a development strategy is not sustainable if :**
  - It involves a significant risk that the economy can be flipped from a desirable state (path) into an undesirable state (path), and if that change is either irreversible or only slowly reversible (Perrings, 2006)

Ecological Perspectives: Ecosystem Services

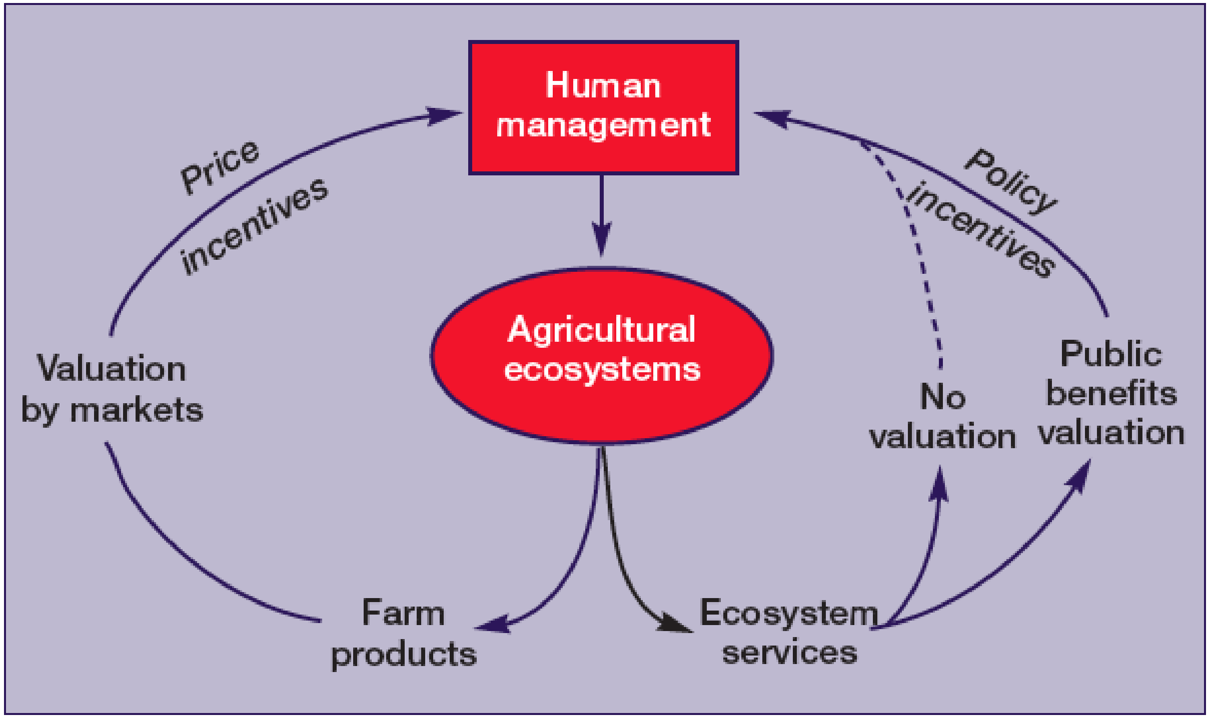
- **Agricultural production can substantially affect the functioning of ecosystems, both positively and negatively**
  - **Growth in global food production over the past half century has required trade offs between ecosystem services, resulting in an overall decline in the supply of these services**

Ecosystem Services

Clean water and air, pollination, disease suppression, habitat for organisms, and carbon storage

Valuing Ecosystem Services

- **Ensuring future agricultural sustainability requires incentives (trade or policy-based) to reward environmental stewardship**



Robertson & Swinton, 2005

Sustainability Lenses

Conceptualizing sustainability through lenses: nutrition, gender, environment, and climate change

Sustainability Lenses

Key dimensions of sustainable agricultural productivity include:

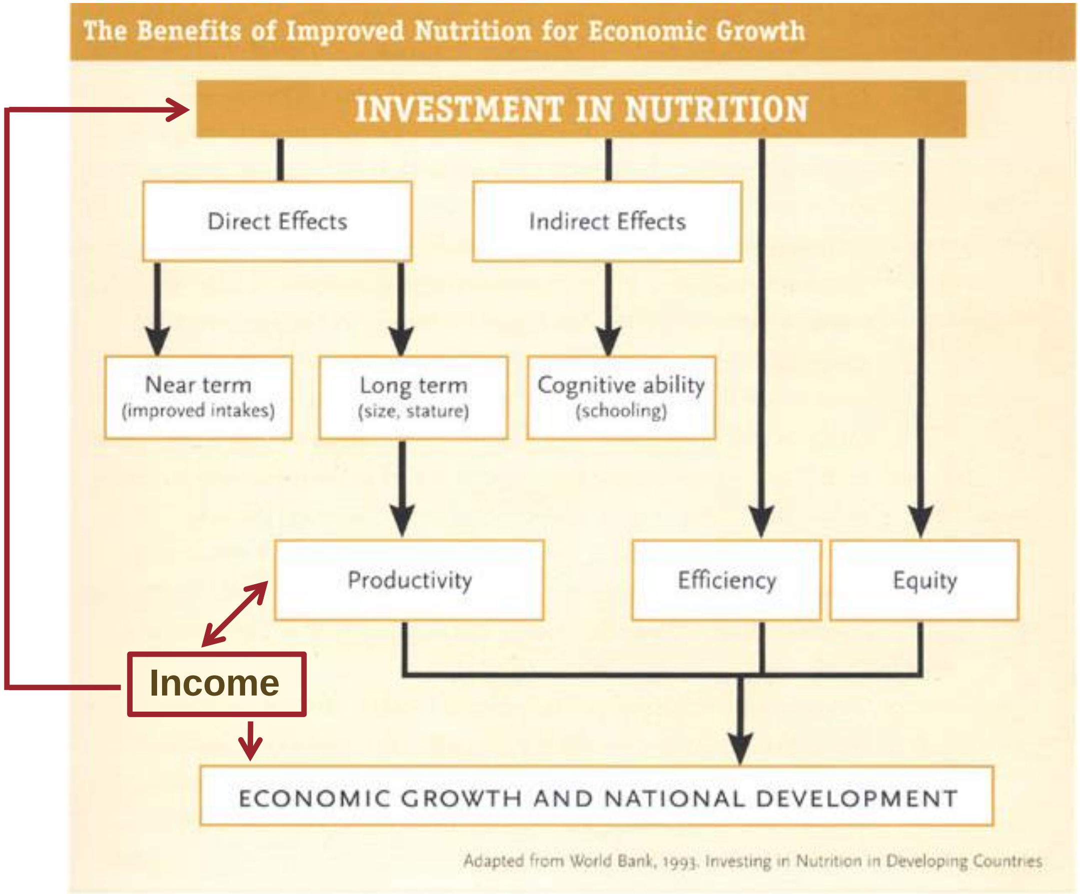
- Nutrition
- Gender
- Environment
- Climate Change

Nutrition & Sustainable Agricultural Productivity

Interaction of nutrition and income and impact on agricultural productivity

Nutrition and Income

- Improved nutrition leads to increased labor productivity;
- Nutrition is a significant determinant of economic productivity.



Source: FAO

Nutrition

Effects of Nutrition on Productivity:

- Per capita calorie and protein intakes shown to have impact on wages
- Several studies suggest iron deficiency reduces work capacity
- Some nutritional studies suggest that causality between income and nutrition runs in both directions

Nutrition and Income:

Ongoing debate in the literature on existence and direction of causal linkages between income and nutrition.

Impact of income on nutrition:

- Among poor households there is a positive correlation between expenditure and calorie intake, *until a certain threshold of intake is reached*;
- Evidence suggests income policies could impact nutrition and intake to some extent;
- However income is not a panacea.

Impact of nutrition on income:

- Depends on the nature of work;
- Protein shown to be more correlated with wages than just calorie intake;
- Only at extremely low levels of calorie intake is nutrition shown to affect productivity;
- Because of impact of protein, raising diet quality has been shown to have high returns.

Nutrition Measurement:

Measuring nutrition availability versus intake:

- Availability: infer intake from food purchased and own production
  - much easier to measure, however potentially less accurate
- Intake: collect information on actual meals consumed (and ingredients used)
  - relies on recall and therefore raises questions of reliability

Nutrition indicators:

- Anthropometry (e.g. height and weight)
- Nutrient intakes
  - Calories consumed
  - Protein intakes
  - Other micro- and macronutrients (e.g. iron)

Summary of Important Concerns Related to Nutrition Measurement:

- How calories are calculated
- How income is defined
- Role of measurement error
- Validity of measurements
- Household composition
    - Adults eat more than children and men more than women
    - Overall findings related to nutrition differ according to gender
- Quantity of calories does not reflect quality

Gender & Sustainable Agricultural Productivity

Impact and components of gender related to agricultural productivity

Gender & Agricultural Productivity

Gender roles in production:
-labor allocation
-land rights & access
-seed & cropping choices
-cash & credit constraints

Household Agricultural Productivity

Gender roles in decisions over use of production:
-cash sales v. own use
-dietary choices for children
-labor allocation

Household health and nutritional status

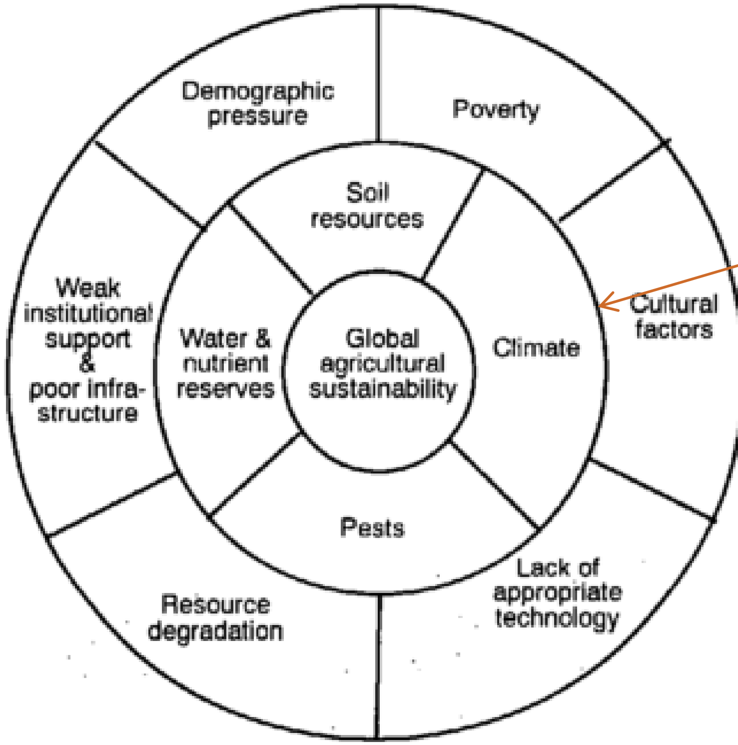
Examples of gender components in household decision-making:

- Women's cash and credit constraints affect household ability to adopt new technologies
- New technologies may alter labor relations in unexpected ways
- Extension services often bypass women
- Gains from technology often accrue to men
- Women's preference for risk and ability to adapt to risk may differ from men's
- Women play a critical role in nutritional decisions of household

Environment & Sustainable Agricultural Productivity

Environmental sustainability as defined by soil and water productivity

Critical Issues of Agricultural Sustainability



Environmental Factors

Socio-economic Factors

Lal, R. and Singh, B.R., 1998

Environment & Sustainable Agricultural Productivity

Two forms of depreciation of natural capital:

- **Environmental degradation**
- **Depletion of natural resources**

Improving yield potential without degradation or depletion means increasing the efficiency of input use for water, soil, nutrients

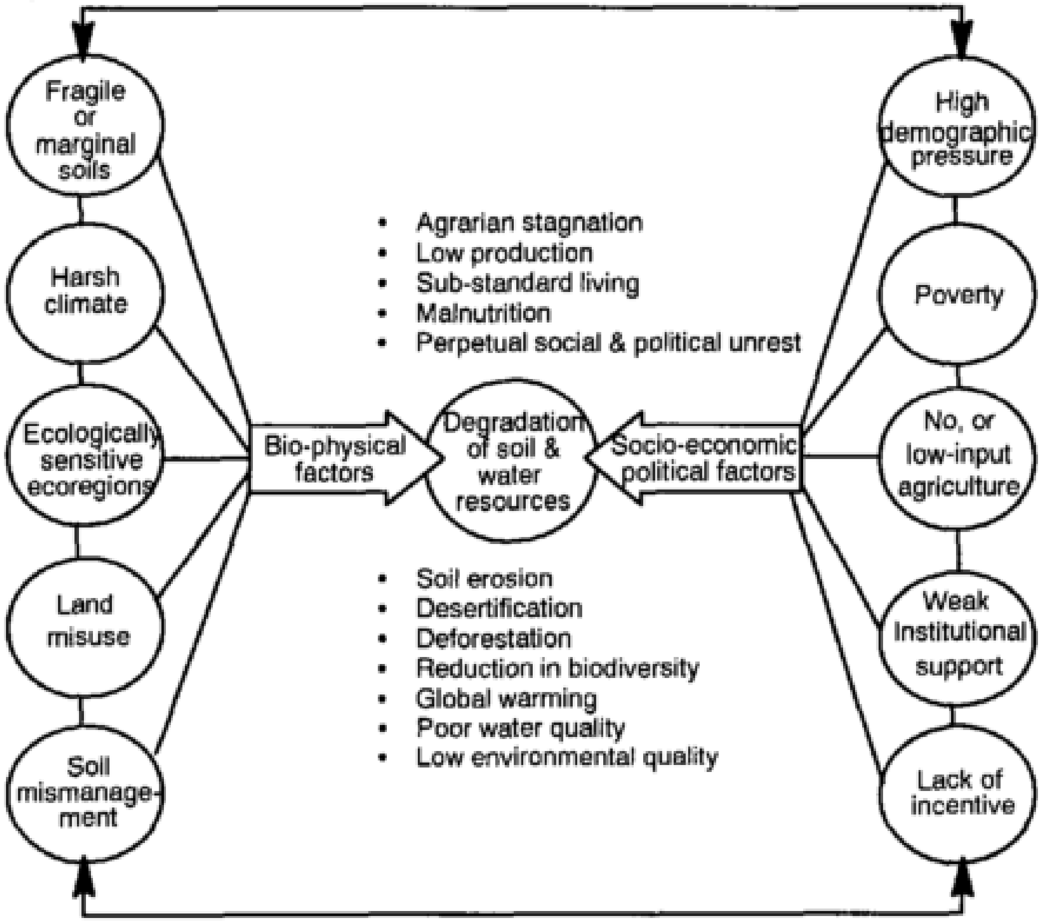
Soil Quality

Soil quality is linked to three components of sustainability:

- Agronomic
- Ecological
- Economic

Impact of soil quality on various sustainability components necessitates the understanding of how soil quality and productivity can be improved.

Soil Degradation: Impacts and Effects



Lal, R. and Singh, B.R., 1998

Soil Degradation

Long-term impact:

- Soil degradation is self-perpetuating and therefore leads to environmental degradation

Ecoregion specific soil maintenance is needed to improve environmental sustainability. Can include:

- Crop rotation
- Judicious use of organic matter and chemical fertilizers
- Integrated pest management

BMGF Agricultural Development Ecosystem Indicators for Soil

Category of Environmental Sustainability	Ecosystem Services by Category	Environmental Variables by Category	Preliminary Ecosystem Indicators (for each environmental variable)
Soils	Nutrient cycling Water purification Support vegetation production Land stabilization	**Organic matter**	Percent soil organic matter
		Nutrient cycling	Nutrient balance (N,P,K,Ca,Mg,S)
		Erosion	Rate of wind erosion Rate of water erosion Soil column thickness
		Salinity control	Electrical conductivity (EC) of root zone soils Sodium adsorption ratio (SAR) of root zone soils Drainage and occurrence of root zone water-logging Soil water holding capacity

BMGF Agricultural Development Ecosystem Indicators for Biodiversity

Category of Environmental Sustainability	Ecosystem Services by Category	Environmental Variables by Category	Preliminary Ecosystem Indicators (for each environmental variable)
Biodiversity	Food provisioning Fiber provisioning Biomass fuel Genetic resources Biochemicals Natural pharmaceuticals Regulation of air quality, climate Regulation of water and erosion Water purification Waste treatment Regulation of diseases, pests Pollination Natural hazard regulation Nutrient cycling Soil formation Production of biological material Photosynthesis Water cycling	**Agricultural species diversity -- plants**	Number of crop types Degree of variation within crop types
		Agricultural species diversity -- animals	Sampling for pollinators Number of livestock types Degree of variation within livestock types
		Wild species diversity -- plants	Aquatic biodiversity Rapid Biodiversity Assessment
		Wild species diversity -- animals	Aquatic biodiversity Rapid Biodiversity Assessment
		Ecosystem continuity	Degree of fragmentation in terms of genetic diversity, buffering, and physical movement
		Resilience to climate change	

Water

Improving water productivity and availability of both surface and groundwater are key elements towards environmental sustainability and overall food security concerns.

Water Productivity

Impacts of decreased water productivity:

- Surface runoff, which leads to soil erosion
- Seepage loss
- Insufficient water availability
  - both surface and groundwater

Effective methods to increase water productivity:

- Improve crop husbandry
- Reallocate canal water from fresh to saline groundwater areas
- Reduce seepage loss in saline groundwater areas

Water Productivity

Constraints of water productivity improvement techniques:

- Adoption rates of techniques tend to be low due to:
  - Start-up costs
  - Issues of land ownership
  - Market access (in case of excess production)

BMGF Agricultural Development Ecosystem Indicators for Water

Category of Environmental Sustainability	Ecosystem Services by Category	Environmental Variables by Category	Preliminary Ecosystem Indicators (for each environmental variable)
Water	Freshwater for drinking, cleaning, cooling, irrigation, and livestock watering	**Surface water -- availability**	Deficit or surplus with respect to total available gallons/year
		Surface water -- quality	Concentrations of nitrates, phosphates, etc.
		Groundwater -- availability	Deficit or surplus with respect to total available gallons/year
		Groundwater -- quality	Concentrations of nitrates, phosphates, etc.

Climate Change & Sustainable Agricultural Productivity

Synthesis of the potential broad impacts of climate change on agricultural productivity

Climate Change and Agriculture

- **Climate change is expected to exacerbate the existing challenges faced by agriculture**
  - **Climate change threatens productivity especially in regions where**
    - Productivity is already low
    - Means of coping with adverse events are limited
  - **Coping with climate change and increasing food security requires:**
    - Higher agricultural productivity
    - Lower output variability in the face of agro-ecological and socio-economic shocks
  - **Achieving more productive and resilient agriculture requires better management of natural resources and higher efficiency in the use of these resources as agricultural inputs**

Responding to Climate Change

- **According to FAO:**
  - **Adopting an ecosystem approach, working at landscape scale and ensuring intersectoral coordination is crucial for effective climate change responses**
  - **Financial support and strengthened institutional capacity will be needed to improve dissemination and enable smallholders to make the transition to "climate-smart" agriculture**

Increasing productivity in agriculture-based developing countries to achieve food security and the needed levels of economic growth, but on a lower emissions trajectory, will require a concerted effort to maximize synergies and minimize tradeoffs between productivity and mitigation.

FAO. (2010). *"Climate-Smart" Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation.* Hague Conference on Agriculture, Food Security & Climate Change.

BMGF Agricultural Development Ecosystem Indicators for Air and Climate

Category of Environmental Sustainability	Ecosystem Services by Category	Environmental Variables by Category	Preliminary Ecosystem Indicators (for each environmental variable)
Air & Climate	Global temperature regulation Water cycling UV protection Oxygen cycling for respiration	**Energy efficiency**	
		Greenhouse gas reduction and mitigation	Greenhouse gas emissions (tonnes of CO2e/ year) Rate of increase in use of fossil fuels
		Air quality	Indoor air pollutants Outdoor air pollutants (particulates, nitrous oxides, sulfur oxides, heavy metals, etc.)

Connecting Sustainability Agricultural Productivity & Human Welfare: The Ecosystem Services Perspective

Ecosystem Services

Provisioning Services

Products obtained from ecosystems

- Food
- Freshwater
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting Services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

FAO. (2007). *"The State of Food and Agriculture: Paying Farmers for Ecosystem Services."*

Ecosystem payments can provide incentives for farmers and consumers to value ecosystem services

- Agriculture can be an important source of improvements in the environmental services provided to humanity by ecosystems
- Ecosystem services are typically not priced at full social value
- Many important ecosystem services have externalities – so farmers do not reap full benefits of conservation efforts
- Required R&D and improvements in knowledge about system are public goods, so underinvestment by private sector is likely

Policy Options

- Green payments to farmers for sustainable practices, landscape preservation
- Removal of subsidies that may encourage overuse of certain inputs
- Certification and benefits for use of auditable practices
- International responses that address cross-border externalities from agricultural production
- Consumer incentives:
  - Labeling that indicates sourcing and full social cost
  - Removing subsidies so that consumers bear full cost of production, at least in developed countries.

Key Summary Points

- **Sustainable agricultural productivity is dependant on (1) economic, (2) ecological, and (3) social factors, all within the context of good governance and a flexible policy environment.**
- **Key dimensions of sustainable agricultural productivity include (1) nutrition, (2) gender, (3) environment, and (4) climate change.**
- **Ecosystem services provide a means for connecting agricultural production to environmental sustainability and human welfare**
- **Ecosystem payments provide one policy option for better management of ecosystem services.**