CROP-ENVIRONMENT SERIES

Maize, Rice, Sorghum/Millets, Sweet Potato/Yam, Cassava

May 5, 2014

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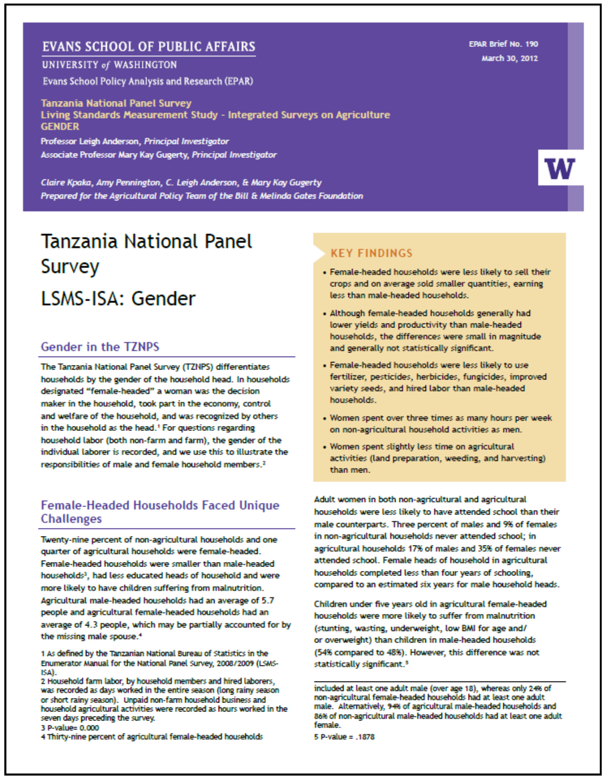

EVANS SCHOOL OF PUBLIC AFFAIRS
UNIVERSITY of WASHINGTON
Evans School Policy Analysis and Research (EPAR)

EPAR Brief No. 190
March 30, 2012

Tanzania National Panel Survey
Living Standards Measurement Study - Integrated Surveys on Agriculture
GENDER

Professor Leigh Anderson, *Principal Investigator*
Associate Professor Mary Kay Gugerty, *Principal Investigator*

Claire Kpaka, Amy Pennington, C. Leigh Anderson, & Mary Kay Gugerty
Prepared for the Agricultural Policy Team of the Bill & Melinda Gates Foundation

Tanzania National Panel Survey

LSMS-ISA: Gender

KEY FINDINGS

- Female-headed households were less likely to sell their crops and on average sold smaller quantities, earning less than male-headed households.
- Although female-headed households generally had lower yields and productivity than male-headed households, the differences were small in magnitude and generally not statistically significant.
- Female-headed households were less likely to use fertilizer, pesticides, herbicides, fungicides, improved variety seeds, and hired labor than male-headed households.
- Women spent over three times as many hours per week on non-agricultural household activities as men.
- Women spent slightly less time on agricultural activities (land preparation, weeding, and harvesting) than men.

Gender in the TZNPS

The Tanzania National Panel Survey (TZNPS) differentiates households by the gender of the household head. In households designated "female-headed" a woman was the decision maker in the household, took part in the economy, control and welfare of the household, and was recognized by others in the household as the head.[1] For questions regarding household labor (both non-farm and farm), the gender of the individual laborer is recorded, and we use this to illustrate the responsibilities of male and female household members.[2]

Female-Headed Households Faced Unique Challenges

Twenty-nine percent of non-agricultural households and one quarter of agricultural households were female-headed. Female-headed households were smaller than male-headed households[3], had less educated heads of household and were more likely to have children suffering from malnutrition. Agricultural male-headed households had an average of 5.7 people and agricultural female-headed households had an average of 4.3 people, which may be partially accounted for by the missing male spouse.[4]

Adult women in both non-agricultural and agricultural households were less likely to have attended school than their male counterparts. Three percent of males and 9% of females in non-agricultural households never attended school; in agricultural households 17% of males and 35% of females never attended school. Female heads of household in agricultural households completed less than four years of schooling, compared to an estimated six years for male household heads.

Children under five years old in agricultural female-headed households were more likely to suffer from malnutrition (stunting, wasting, underweight, low BMI for age and/or overweight) than children in male-headed households (54% compared to 48%). However, this difference was not statistically significant.[5]

1 As defined by the Tanzanian National Bureau of Statistics in the Enumerator Manual for the National Panel Survey, 2008/2009 (LSMS-ISA).
2 Household farm labor, by household members and hired laborers, was recorded as days worked in the entire season (long rainy season or short rainy season). Unpaid non-farm household business and household agricultural activities were recorded as hours worked in the seven days preceding the survey.
3 P-value= 0.000
4 Thirty-nine percent of agricultural female-headed households included at least one adult male (over age 18), whereas only 24% of non-agricultural female-headed households had at least one adult male. Alternatively, 94% of agricultural male-headed households and 86% of non-agricultural male-headed households had at least one adult female.
5 P-value = .1878

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- Portfolio analysis and strategy support

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WHY

Environmental Impact Overview
Context and Motivation

HOW

Methods & Scope
Depth of research by crop and region

WHAT

Crop and Geographic Highlights
Major constraints and impacts

AGENDA

Why Productivity not Yield?

Productivity accounts for the value of multiple outputs (e.g. intercropping, crops, livestock) and the cost of various inputs (labor, fertilizer…)

In practice grantees:

- ❑ Most often measure yield, and
- ❑ Measure yield in different ways

YIELD IMPROVING INTERVENTION	POTENTIAL COSTS
Mono-cropping	• Reduced production of other crops • Loss of biodiversity • Increased pests
Intensive cultivation	• Erosion, nutrient depletion • Increased labor costs
Application of fertilizers/pesticides	• Increased input and credit costs • Pollution, loss of pollinators / intercrops

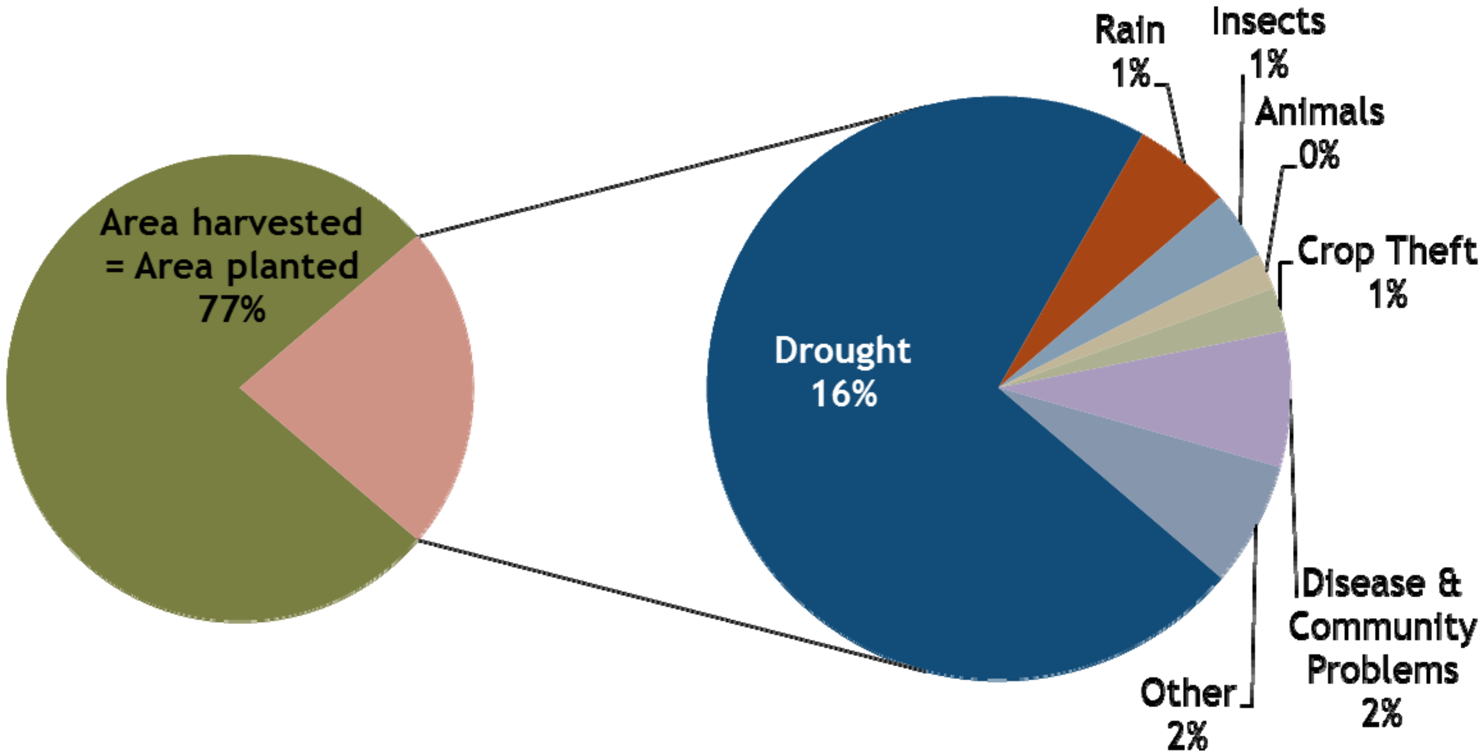
Why *Sustainable* Productivity?

Productivity → **Sustainable Productivity**

$$\frac{\text{Outputs}}{\text{Inputs}} \qquad \frac{\text{Supportable Outputs}}{\text{Viable Inputs}}$$

PRODUCTIVITY CONCERNS	SUSTAINABLE PRODUCTIVITY CONCERNS
Labor costs	Women's labor
Input costs	Input types/sources (renewable/non-renewable)
Yield: crop output in kg/hectare	**Value**: crop and intercrop output in nutrients, also environmental and social impacts

The Environment & Sustainable Productivity: **Constraints**



Farmer-reported reasons for loss in area between planting and harvesting on long rainy season plots

[From EPAR's Rice Yield and Productivity Measures Brief]

The Environment & Sustainable Productivity: **Impacts**

- Farmer adaptations in any given cropping season have implications for the regional and global environment (negative externalities like habitat loss, climate change)

- Farm practices also have environmental impacts with consequences for the farmer in future crop cycles (nutrient depletion, soil structure damage)

- The latter impacts are not negative externalities (impacting others), but rather **costs incurred by the farmer** in the next production cycle

The Environment & Sustainable Productivity: **Good Practices**

Sustainably productive agricultural systems:

- Pursue **input supply from renewable** sources (water, nutrients, labor) and **low levels of stresses**
- Ensure **efficient** use of those resources in producing **useful outputs**
- Enable **high cycling** of resources within the farming system, reducing losses in the system and offtake
- Maintain **environment/ecosystem services**
- Include well developed **farmer management systems**

...and the ways to assess these priorities

Why Measure Sustainable Productivity Operationally?

Opportunities to Incorporate Environmental Considerations into Grant Making

Programming	• Incorporate environmental considerations throughout programming • Encourage good practices
Measurement	• Understand where gaps in the literature exist • Use opportunities to measure environmental indicators, evaluate and learn about crop-environment interactions
Awareness	• Increase awareness of potential negative impacts of promoting increased crop (and livestock) productivity • Recognize "red flag" environmental constraints and impacts associated with production practices

WHY

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AGENDA

Crop x Environment Briefs

❑ *Agriculture-Environment Overview*

<u>Content</u>

- Environmental constraints
- Environmental impacts
- Depth of research on crop-environment interactions
- Cropping systems in SSA and SA
- Key environmental impacts

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Evans School Policy Analysis and Research (EPAR)
Professor Leigh Anderson, PI and Lead Faculty
Associate Professor Mary Kay Gugerty, Lead Faculty

Agriculture-Environment Series:
Current Knowledge of Crop-Environment Interactions in Sub-Saharan Africa and South Asia

Travis Reynolds, Stephen R. Waddington, Alexander Chew, Zoe True
C. Leigh Anderson, Alison Cullen and Mary Kay Gugerty

Prepared for the Agricultural Policy Team of the Bill & Melinda Gates Foundation

March 20, 2014

Introduction

This overview introduces a series of briefs in the Agriculture-Environment Series that examine crop-environment interactions for a range of crops in smallholder food production systems in Sub-Saharan Africa (SSA) and South Asia (SA). At the request of the Agricultural Development Group of the Bill and Melinda Gates Foundation, the briefs cover the following important food crops in those regions; rice, maize, sorghum/millets, sweetpotato/yam, and cassava.

scholarship and to identify apparent gaps in research on crop-environment interactions:

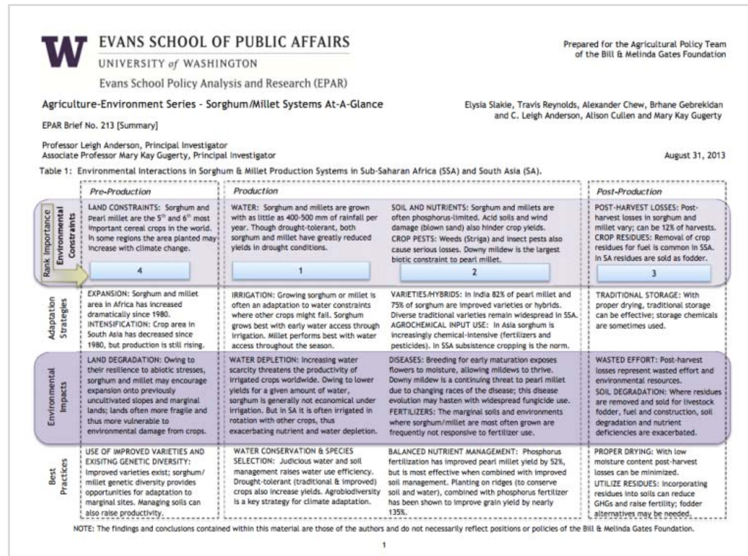
I. Severity of Environmental Constraints Reported

The relative contributions of major biotic and abiotic constraints to crop yields are increasingly available in the peer-reviewed literature, including recent and cross-cutting review articles evaluating constraints in relation to "yield gaps" by crop and by farming system (see for example Waddington *et al.*, 2010; Dixon *et al.*, 2001).

❑ *Crop Specific Environmental Briefs*

<u>Content</u>

- Constraints by production stage (pre-production, production, and post-harvest)
- Good practices
- Climate change impacts



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Prepared for the Agricultural Policy Team of the Bill & Melinda Gates Foundation

Agriculture-Environment Series - Sorghum/Millet Systems At-A-Glance

Elysia Slakie, Travis Reynolds, Alexander Chew, Brhane Gebrekidan and C. Leigh Anderson, Alison Cullen and Mary Kay Gugerty

EPAR Brief No. 213 [Summary]

Professor Leigh Anderson, Principal Investigator
Associate Professor Mary Kay Gugerty, Principal Investigator

August 31, 2013

Table 1: Environmental Interactions in Sorghum & Millet Production Systems in Sub-Saharan Africa (SSA) and South Asia (SA).

	Pre-Production	*Production*		*Post-Production*
Environmental Constraints	LAND CONSTRAINTS: Sorghum and Pearl millet are the 5th and 6th most important cereal crops in the world. In some regions the area planted may increase with climate change.	WATER: Sorghum and millets are grown with as little as 400-500 mm of rainfall per year. Though drought-tolerant, both sorghum and millet have greatly reduced yields in drought conditions.	SOIL AND NUTRIENTS: Sorghum and millets are often phosphorus-limited. Acid soils and wind damage (blown sand) also hinder crop yields. CROP PESTS: Weeds (Striga) and insect pests also cause serious losses. Downy mildew is the largest biotic constraint to pearl millet.	POST-HARVEST LOSSES: Post-harvest losses in sorghum and millet vary; can be 12% of harvests. CROP RESIDUES: Removal of crop residues for fuel is common in SSA. In SA residues are sold as fodder.
Rank Importance	4	1	2	3
Adaptation Strategies	EXPANSION: Sorghum and millet area in Africa has increased dramatically since 1980. INTENSIFICATION: Crop area in South Asia has decreased since 1980, but production is still rising.	IRRIGATION: Growing sorghum or millet is often an adaptation to water constraints where other crops might fail. Sorghum grows best with early water access through irrigation. Millet performs best with water access throughout the season.	VARIETIES/HYBRIDS: In India 82% of pearl millet and 75% of sorghum are improved varieties or hybrids. Diverse traditional varieties remain widespread in SSA. AGROCHEMICAL INPUT USE: In Asia sorghum is increasingly chemical-intensive (fertilizers and pesticides). In SSA subsistence cropping is the norm.	TRADITIONAL STORAGE: With proper drying, traditional storage can be effective; storage chemicals are sometimes used.
Environmental Impacts	LAND DEGRADATION: Owing to their resilience to abiotic stresses, sorghum and millet may encourage expansion onto previously uncultivated slopes and marginal lands; lands often more fragile and thus more vulnerable to environmental damage from crops.	WATER DEPLETION: Increasing water scarcity threatens the productivity of irrigated crops worldwide. Owing to lower yields for a given amount of water, sorghum is generally not economical under irrigation. But in SA it is often irrigated in rotation with other crops, thus exacerbating nutrient and water depletion.	DISEASES: Breeding for early maturation exposes flowers to moisture, allowing mildews to thrive. Downy mildew is a continuing threat to pearl millet due to changing races of the disease; this disease evolution may hasten with widespread fungicide use. FERTILIZERS: The marginal soils and environments where sorghum/millet are most often grown are frequently not responsive to fertilizer use.	WASTED EFFORT: Post-harvest losses represent wasted effort and environmental resources. SOIL DEGRADATION: Where residues are removed and sold for livestock fodder, fuel and construction, soil degradation and nutrient deficiencies are exacerbated.
Best Practices	USE OF IMPROVED VARIETIES AND EXISITNG GENETIC DIVERSITY: Improved varieties exist; sorghum/millet genetic diversity provides opportunities for adaptation to marginal sites. Managing soils can also raise productivity.	WATER CONSERVATION & SPECIES SELECTION: Judicious water and soil management raises water use efficiency. Drought-tolerant (traditional & improved) crops also increase yields. Agrobiodiversity is a key strategy for climate adaptation.	BALANCED NUTRIENT MANAGEMENT: Phosphorus fertilization has improved pearl millet yield by 52%, but is most effective when combined with improved soil management. Planting on ridges (to conserve soil and water), combined with phosphorus fertilizer has been shown to improve grain yield by nearly 135%.	PROPER DRYING: With low moisture content post-harvest losses can be minimized. UTILIZE RESIDUES: Incorporating residues into soils can reduce GHGs and raise fertility; fodder alternatives may be needed.

NOTE: The findings and conclusions contained within this material are those of the authors and do not necessarily reflect positions or policies of the Bill & Melinda Gates Foundation.

1

Using the EPAR Environment Series

- ❑ In-depth analysis by crop:
  - ❑ Rice, Maize, Sorghum/Millets, Sweetpotato/Yam, Cassava
- ❑ "Good practice" insights & recommendations:
  - ❑ Land & soil management
  - ❑ Integrated pest management
  - ❑ Intercropping & agro-biodiversity
- ❑ Research gaps & limitations

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Agriculture-Environment Series:
Current Knowledge of Crop-Environment Interactions in Sub-Saharan Africa and South Asia

EPAR Brief No. 20**

Travis Reynolds, Stephen R. Waddington, Alexander Chew, Zoe True
C. Leigh Anderson, Alison Cullen and Mary Kay Gugerty

Prepared for the Agricultural Policy Team of the Bill & Melinda Gates Foundation

March 20, 2014

Introduction

This overview introduces a series of briefs in the Agriculture-Environment Series that examine crop-environment interactions for a range of crops in smallholder food production systems in Sub-Saharan Africa (SSA) and South Asia (SA). The EPAR briefs cover the following important food crops in those regions; rice (#208), maize (#218), sorghum/millets (#213), sweetpotato/yam (#225), and cassava (#228).

Drawing on the academic literature and the field expertise of crop scientists, these briefs highlight crop-environment interactions at three stages of the crop value chain: pre-production (e.g., land clearing and tilling), production (such as water, nutrient and other input use), and post-production (e.g., waste disposal and crop storage). At each stage we emphasize environmental constraints on crop yields (including poor soils, water scarcity, crop pests) and impacts of crop production on the environment (such as soil erosion, water depletion and pest resistance). We then highlight good practices from the literature and from expert experience for minimizing negative environmental impacts in smallholder crop production systems.

This overview (along with the accompanying detailed crop briefs) seeks to provide a framework for stimulating across-crop discussions and informed debates on the full range of crop-environment interactions in agricultural development initiatives.

Content of the Overview and Crop Briefs

We begin this overview by describing our methodology for ranking crop-environment interactions, and follow by introducing the major smallholder farming systems in which the crops are grown in SSA and SA. We thenhighlight key environmental constraints and impacts with the crops and systems through the value chain, details of which are available in the five EPAR crop-environment briefs. Each of these detailed briefs in turn includes a summary table identifying key environmental constraints and environmental impacts of the selected food crop in farming systems in SSA and SA. These full briefs further summarize good practices identified in the literature to address environmental problems associated with the crops. While the detailed briefs are crop-focused, the appendices of this overview presents relevant crop information broken out by region: SSA and SA, and a summary of the research by region.

We evaluate the importance of crop-environment interactions by assessing the frequency with which an environmental constraint to crop production, or environmental impact from crop production, is mentioned in the peer-reviewed literature, and whether it is characterized in that literature as minor, moderate or severe. Recognizing that this accounting depends on the stock of literature, we report on the depth of the literature for each crop, to allow the reader to calibrate the results by the amount of research that has been conducted.

We use three criteria to summarize the empirical evidence currently available in peer-reviewed scholarship and to identify apparent gaps in research on crop-environment interactions:

I. Severity of Environmental Constraints Reported

The relative effects of major biotic and abiotic constraints on crop yields are increasingly available in the peer-reviewed literature, including recent and cross-cutting review articles evaluating constraints in relation to 'yield gaps' by crop and by farming system (see for example Waddington *et al.*, 2010; Dixon *et al.*, 2001). Some of these cross-cutting crop-level estimates of constraints and yield gaps are given in the individual crop-environment briefs. In this overview we summarize for six general categories the relative significance of various environmental constraints on crop production as determined based on a comprehensive review of published literature and consultation with crop experts. The categories were land availability, nutrient constraints, water constraints, biotic constraints, climate change, and post-harvest losses. These same categories are used in the summary table at the beginning of each detailed crop brief.

We categorize the severity of these categories of environmental constraints for each crop as follows:

0. *No mentions of the environmental constraint in published literature or expert accounts on the crop*
1. *Rarely mentioned or a minor constraint*
2. *Sometimes mentioned as a moderate constraint*
3. *Consistently mentioned as a moderate constraint*
4. *Sometimes mentioned as a severe constraint*
5. *Consistently mentioned in published literature or expert accounts on the crop as a severe constraint*

Wherever possible at least two experts with expertise specific to each crop validated the categorizations; in any remaining cases the authors used their own judgment based on expert input and their own assessments of the available evidence. The resultant categorization indicates the relative importance, in very broad terms, of different environmental constraints on crop yields. Further details on each type of constraint can be found in the accompanying briefs on each crop.

Page 1

Methods

- ❑ Assessments of constraints to crops, key crop environmental impacts by small expert panels and adaptation strategies

Environmental constraint categories:

land availability
nutrient constraints
water constraints
biotic constraints
climate change
post-harvest losses

Environmental impact categories:

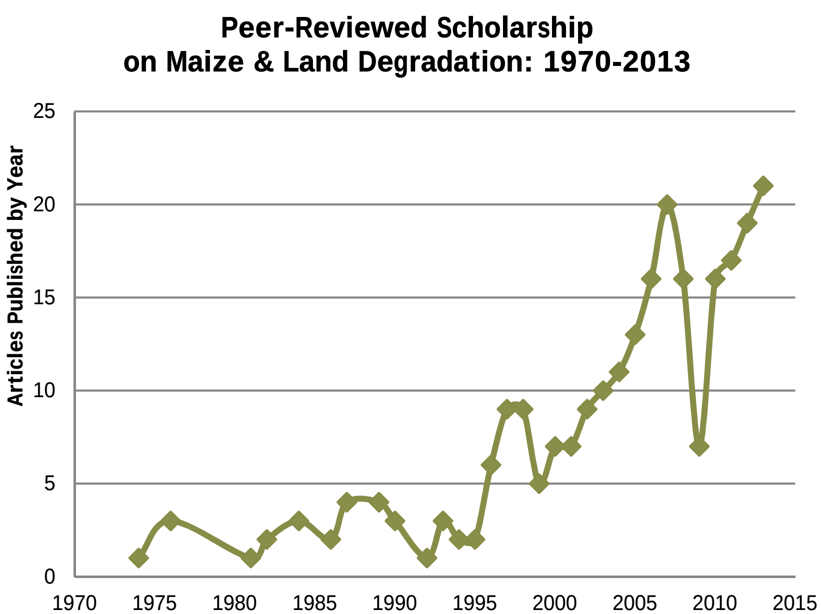
land degradation
wild biodiversity loss
agro-biodiversity loss
water depletion
water pollution
soil nutrient depletion
soil pollution
pest outbreaks & resistance
greenhouse gas (GHG) emissions (CH_4 or N_2O)
air pollution
storage chemicals
post-harvest losses

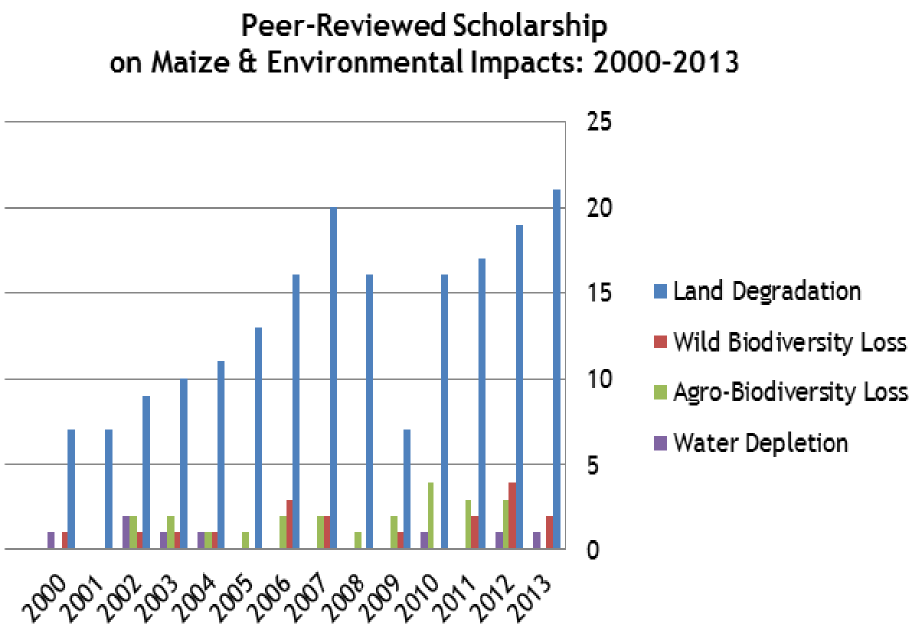
Methods

❑ In-depth review and interpretation of published and gray literature on crop-environment interactions

- ❑ Scopus searches for published research on environmental topics

EXAMPLE SEARCH: *(maize) AND (erosion OR degradation OR "slash and burn" OR "slash-and-burn" OR "soil conservation" OR "conservation tillage") AND (africa OR niger* OR ethiopia OR tanzania)*





Methods

- Classification of severity of crop environmental impacts:

  0. No mentions of the environmental impact in published literature or expert accounts on the crop

  1. Rarely mentioned or a minor impact

  2. Sometimes mentioned as a moderate impact

  3. Consistently mentioned as a moderate impact

  4. Sometimes mentioned as a severe impact

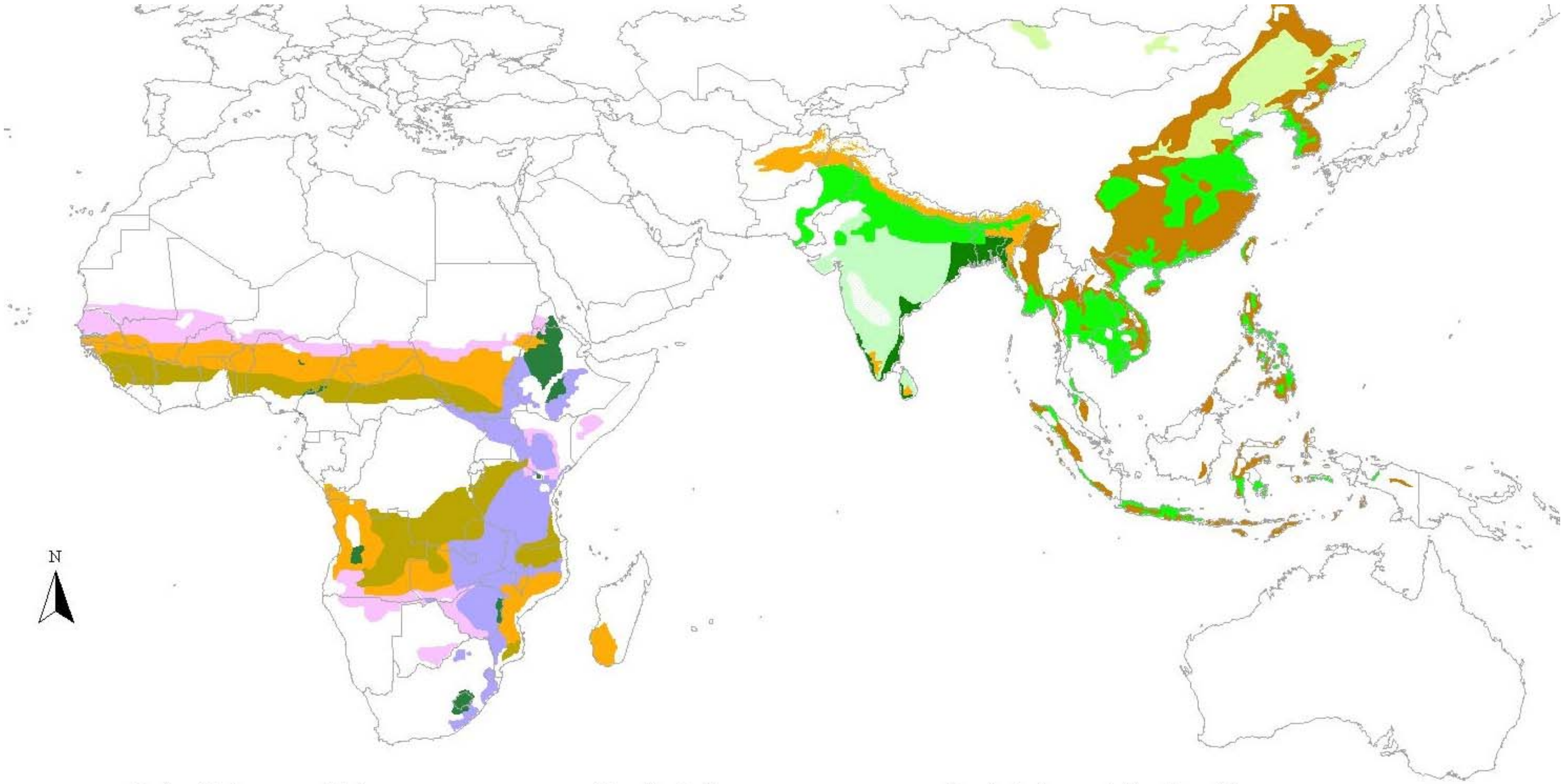
  5. Consistently mentioned in published literature or expert accounts as a severe environmental impact

Caveats for Crop-Environment Analyses

- Non-crop specific constraints and impacts may be under-emphasized
- Farm system and agro-ecological zone matter (as does the role of livestock)
- Responses to environmental impacts will vary with the context

Cereal & Root Crop Farming Systems

in SS Africa and Asia



Sub - Saharan Africa

- Highland temperate mixed
- Root crop
- Cereal-root crop mixed
- Maize mixed
- Agro-pastoral millet/sorghum

South Asia

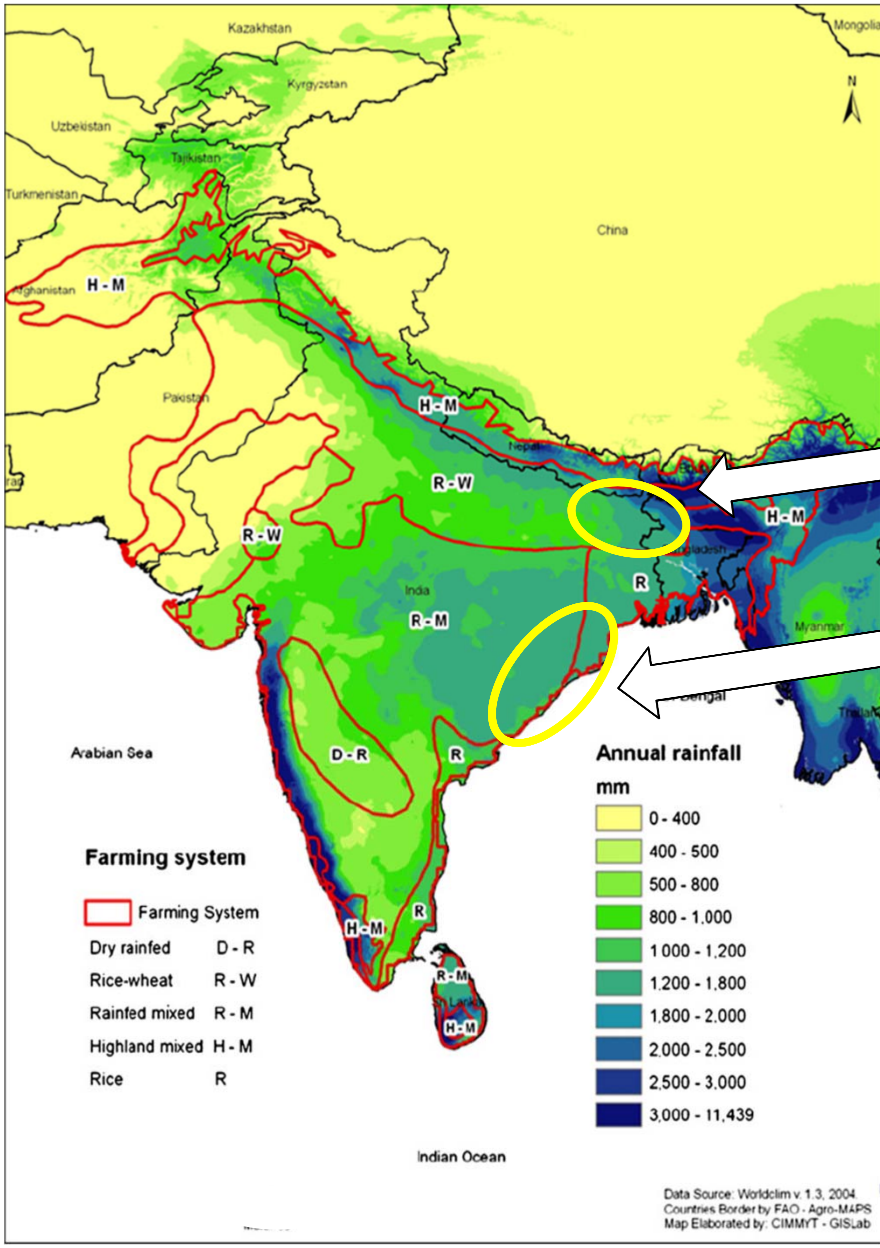
- Rice
- Rice-wheat
- Highland mixed
- Rainfed mixed
- Dry rainfed

East Asia and the Pacific

- Lowland rice
- Upland intensive mixed
- Temperate mixed

Based on Dixon et al (2001)

South Asian Farming Systems & Annual Rainfall



State of Bihar

State of Odisha

WHY

Environmental Impact Overview

Context and Motivation

HOW

Methods & Scope

Depth of research by crop and region

WHAT

Crop and Geographic Highlights

Major constraints and impacts

AGENDA

Sustainable Productivity Growth

for key crops (and cropping systems)

Reduced Environmental Constraints to Crop Production

e.g., better soils, water abundance, fewer crop pests-diseases-weeds, appropriate temperatures

Reduced Impact of Cropping on the Environment

e.g., less deforestation, biodiversity loss, soil erosion, nutrient mining, water depletion, pest resistance, soil-water-air pollution

Increased Environmental Services & Reduced Environmental Degradation

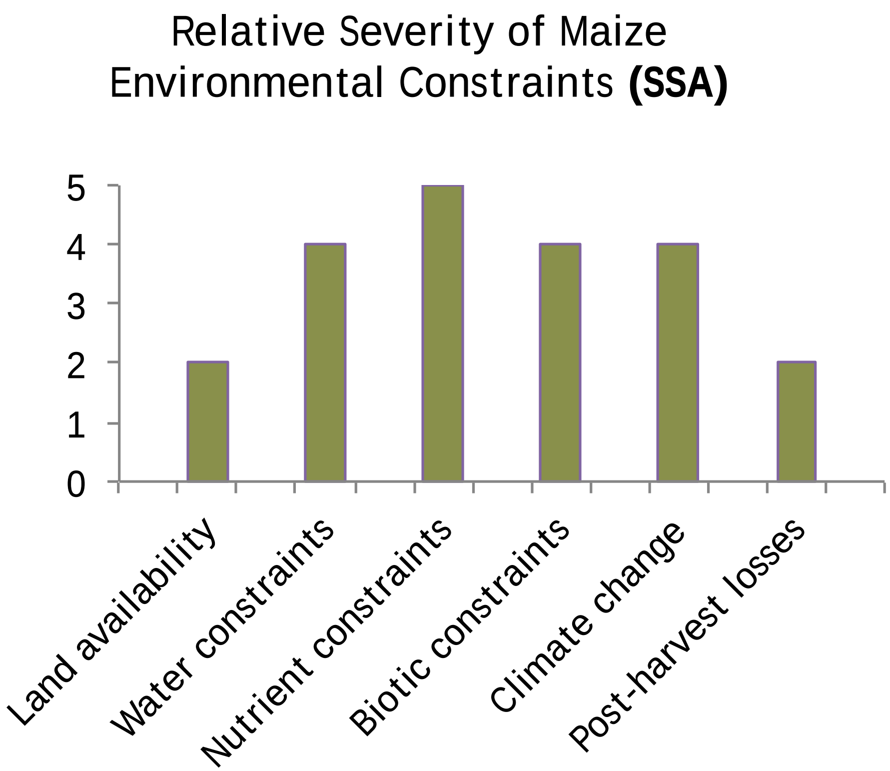
e.g., land/soil quality, wild biodiversity, agro-biodiversity, water availability, water quality, soil nutrient status, pest status, greenhouse gases, air quality, storage chemicals

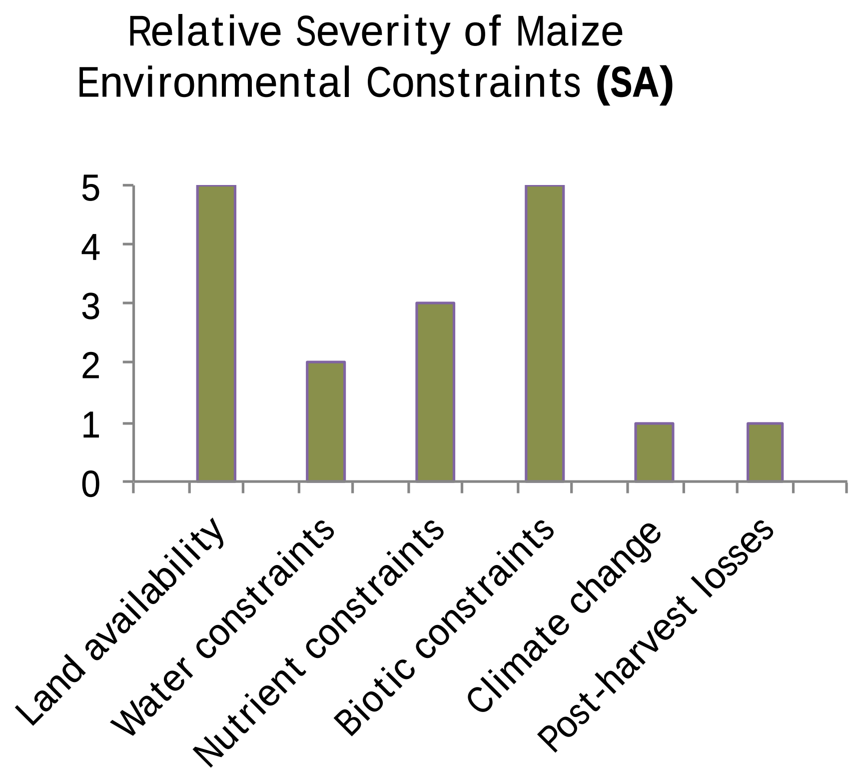
Ex: Crop-Environment Interactions

Constraint: Cassava growing on a nutrient-depleted sandy soil in southern Africa

Impact: Newly-emerged maize planted on bare sloping land in South Asia

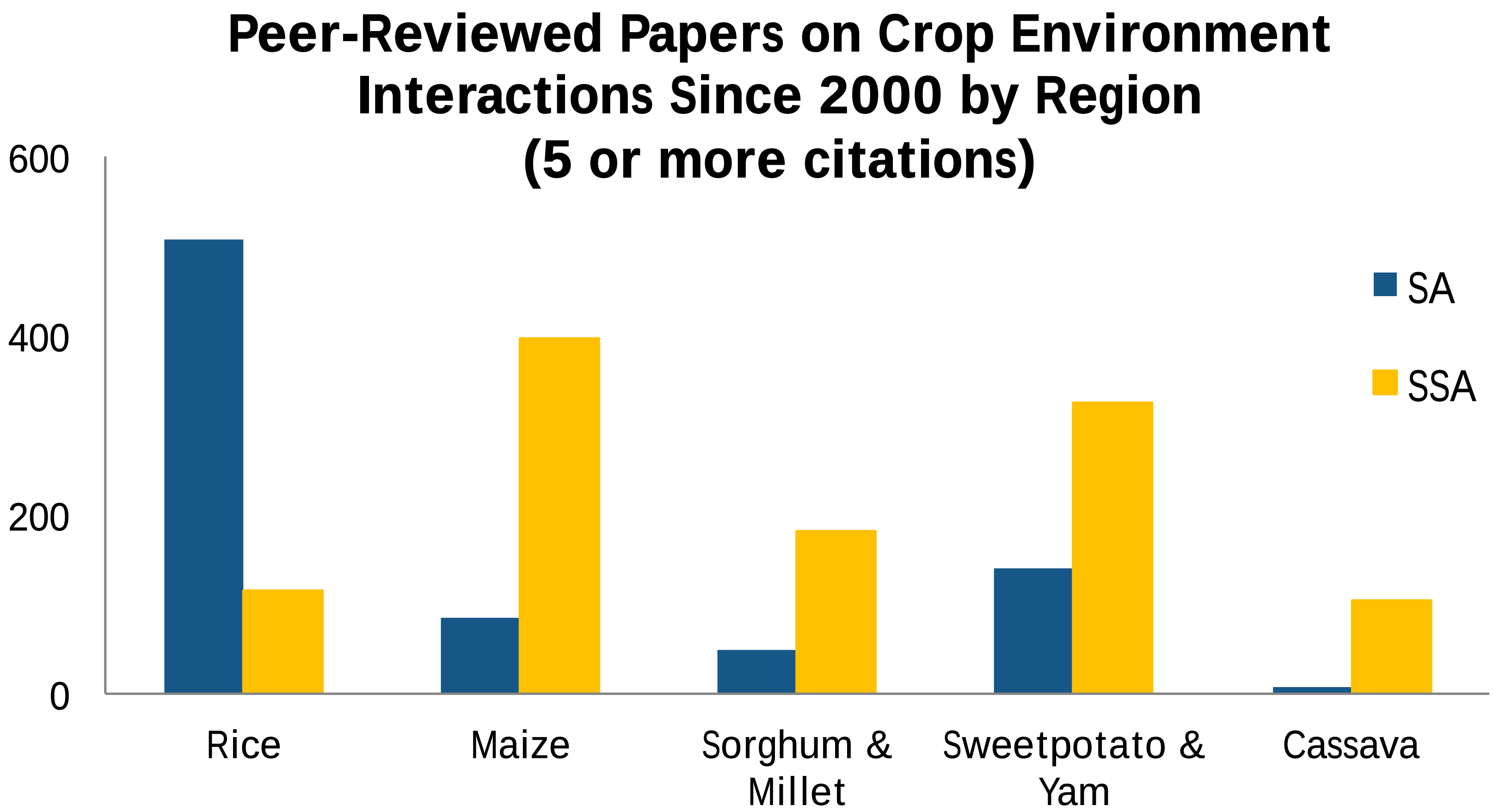
Summary of Environmental Constraints
e.g. for Maize





Impacts of Crops on the Environment, by Crop

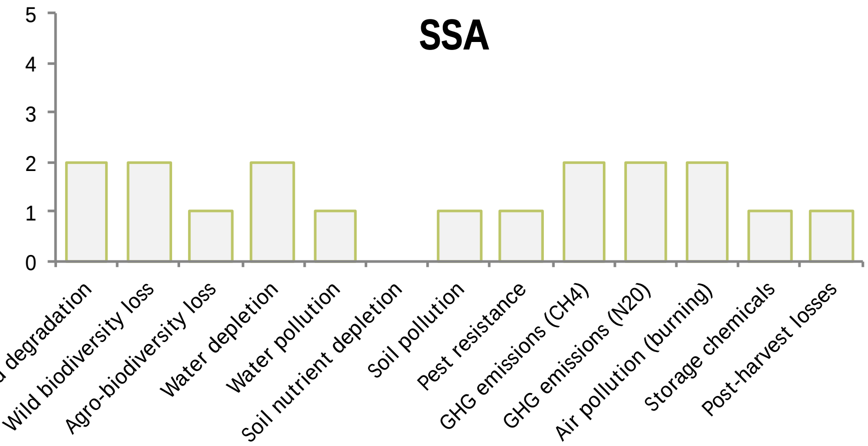
Depth of Crop x Environment Research Literature

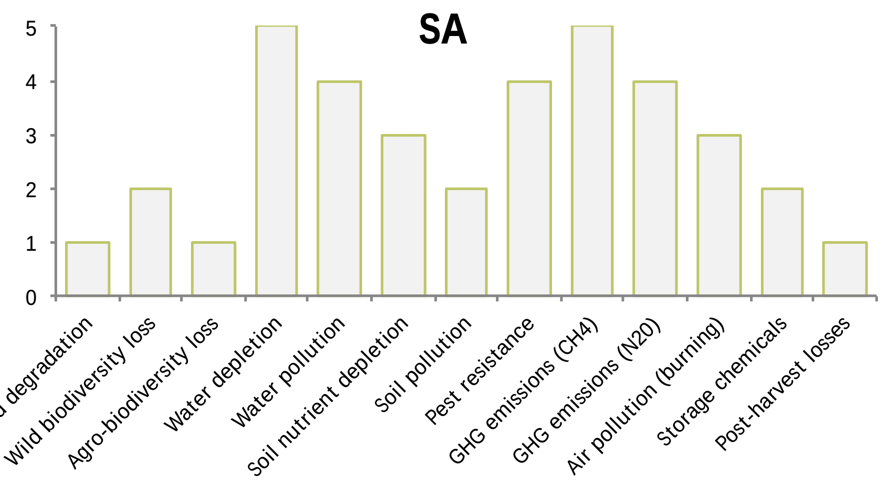


Rice

- Intensive monoculture rice systems increase yields but have higher environmental impacts.
- In SSA, land degradation and conversion of sensitive ecosystems are key threats.
  - Newly expanding rice areas
- In SA water depletion & pollution, pest resistance, and GHG emissions among the most severe impacts.
  - Rice already long-established

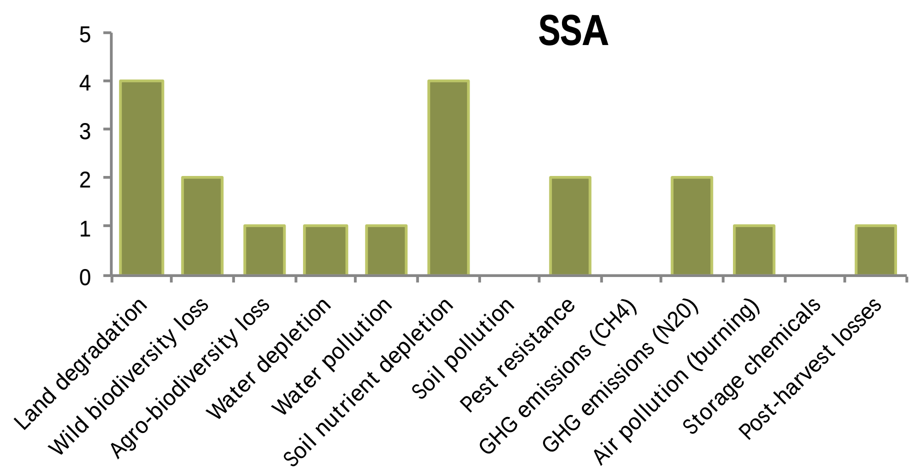
Relative Severity of Rice Environmental Impacts in SSA and SA

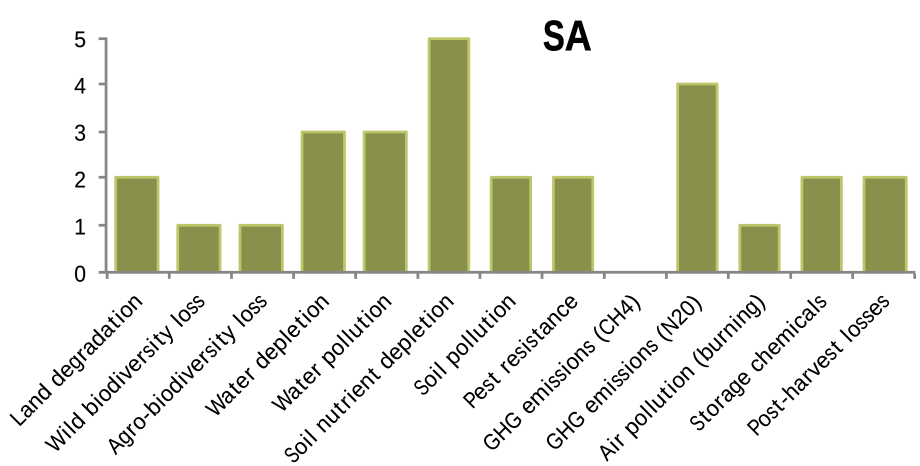




Maize

Relative Severity of Maize Environmental Impacts



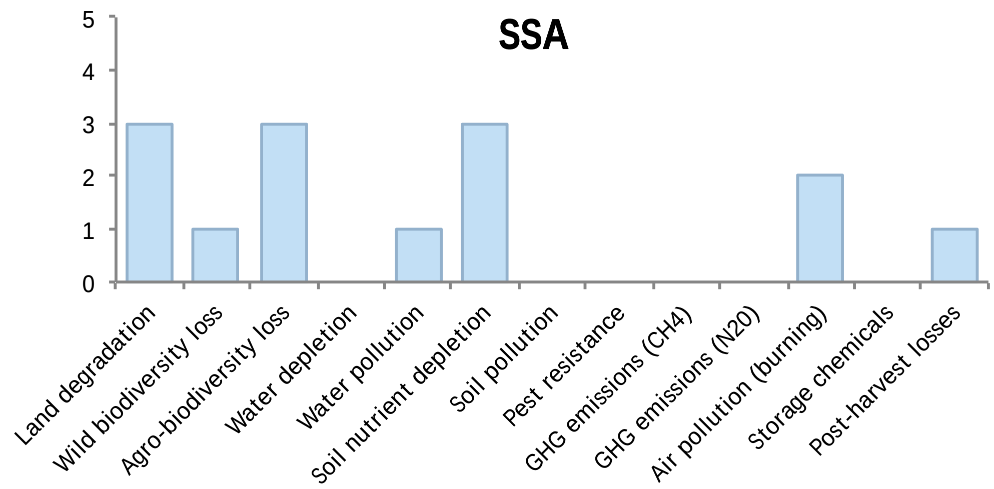


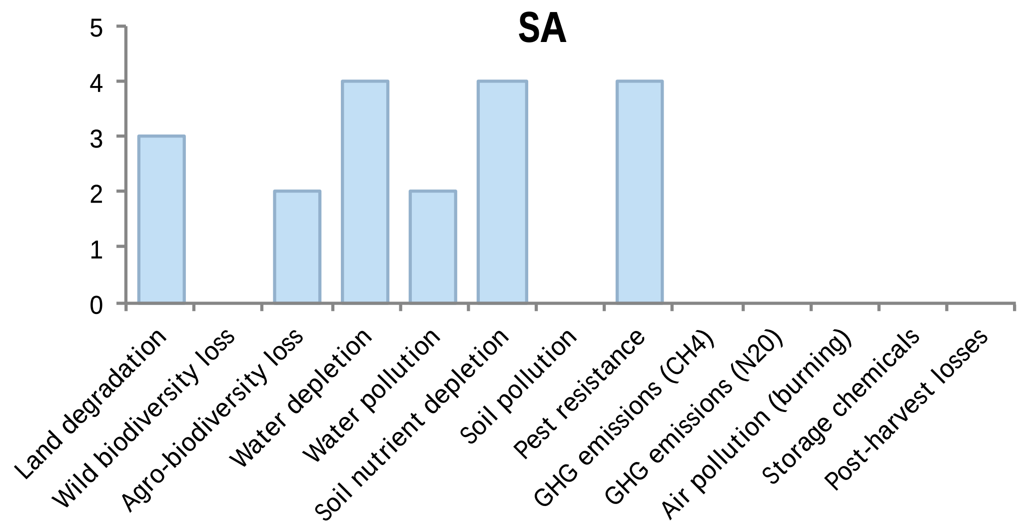
- ❑ Between 1961 and 2010 maize area harvested increased 53% worldwide, doubling in SSA.
- ❑ Maize is a common first crop after slash-and-burn clearing in SSA leading to biodiversity loss and GHG emissions.
- ❑ Repeated plantings with poor fertility management leads to nutrient mining.
- ❑ Climate change will exacerbate biotic and abiotic constraints to maize, including temperature & drought, pests, and suitable land.

Sorghum/Millets

- Suitability for marginal (dry) lands means these crops are often grown in ecologically fragile areas.
- Pressures from climate change may mean expansion of these production systems.
- Crop residues can mitigate impacts but there are competing uses as fodder, fuel, etc.
  - Both in extensive (SSA) and intensive (SA) systems

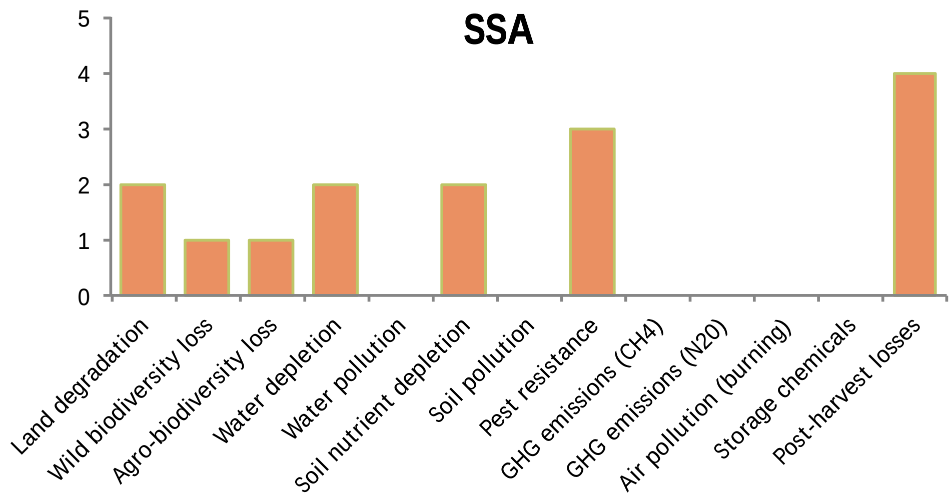
Relative Severity of Sorghum/Millets Environmental Impacts

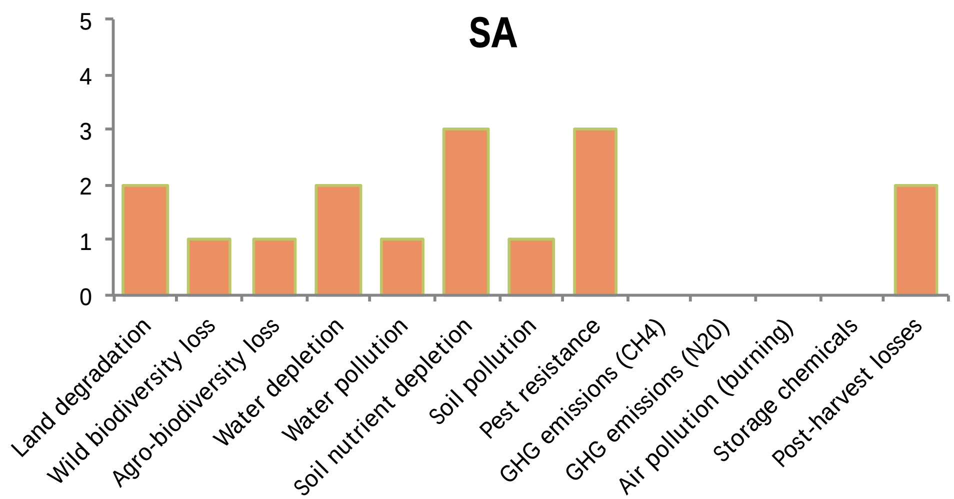




Sweetpotato and Yam

Relative Severity of Sweetpotato /Yam Impacts





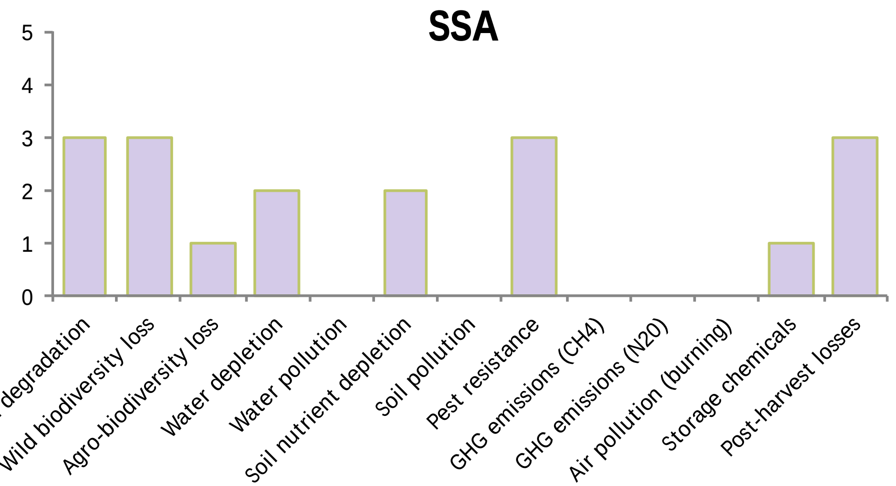
- Modest environmental impacts, partially attributable to sparse cropping and very low-input cropping systems.
- May be more tolerant to climate change than cereals.
- But highly susceptible to pests and disease during crop production and post harvest.

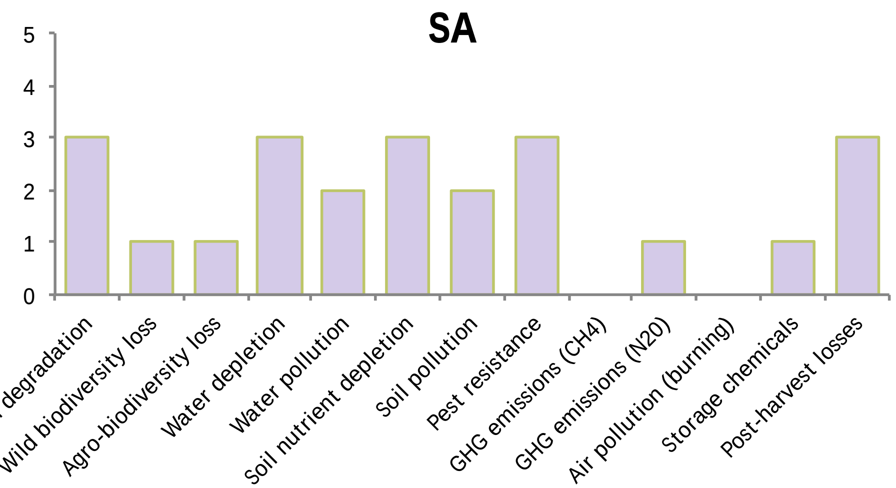
The environmental impact of post-harvest losses includes the cumulative burden of all resources used in production

Cassava

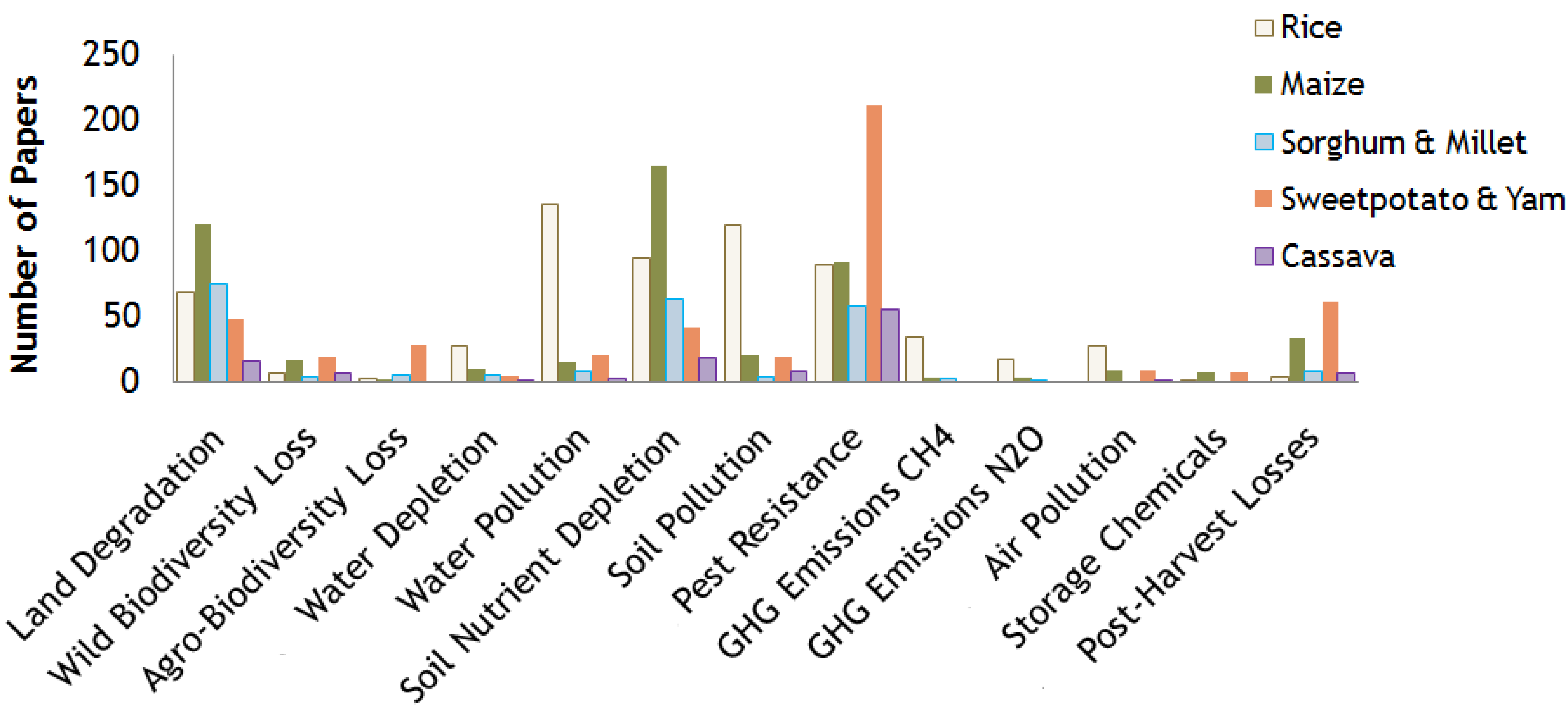
- Role as a food security crop; long presumed low-impact.
- Expansion of cassava into marginal lands in SSA has increased forest loss, soil degradation and erosion.
    - Last-resort crop on depleted fields before bush fallows.
- High susceptibility to diseases and pests.
- Difficulties with post-harvest storage and processing.

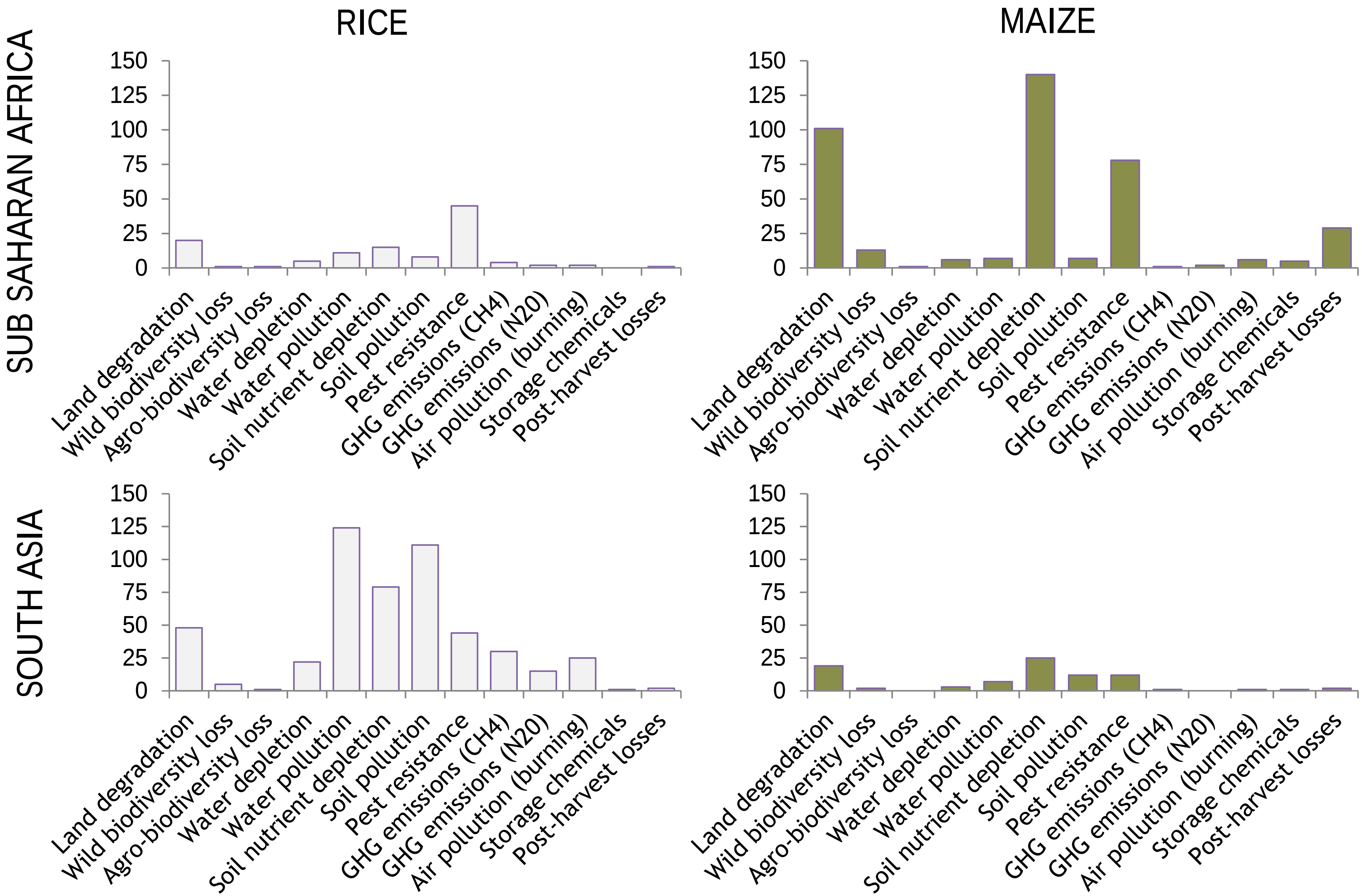
Relative Severity of Cassava Environmental Impacts



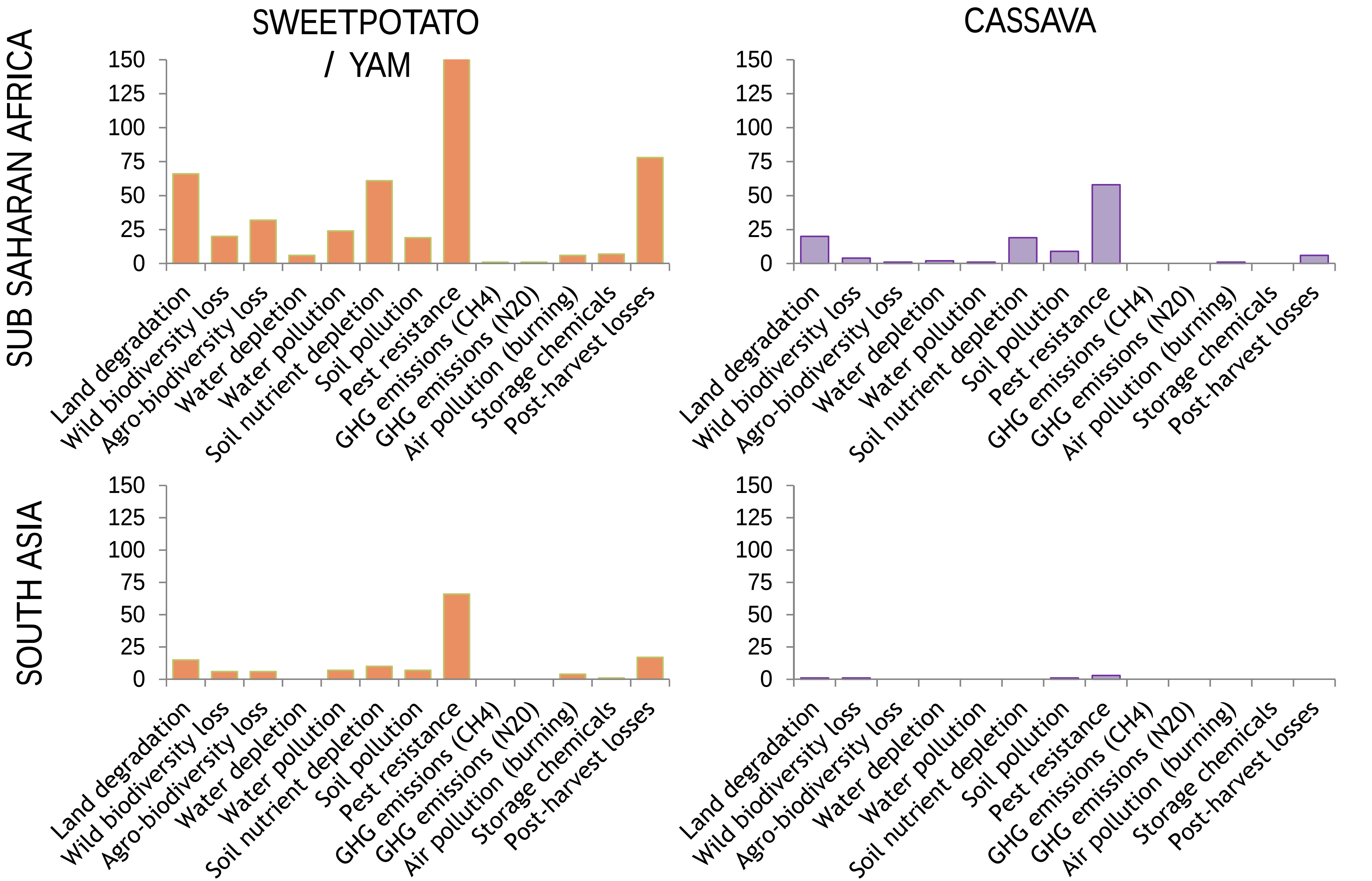


Depth of Crop x Environment Research Literature, and Gaps





RICE
MAIZE
SUB SAHARAN AFRICA
SOUTH ASIA
150
125
100
75
50
25
0
Land degradation
Wild biodiversity loss
Agro-biodiversity loss
Water depletion
Water pollution
Soil nutrient depletion
Soil pollution
Pest resistance
GHG emissions (CH4)
GHG emissions (N20)
Air pollution (burning)
Storage chemicals
Post-harvest losses


SWEETPOTATO / YAM
CASSAVA
SUB SAHARAN AFRICA
SOUTH ASIA
150
125
100
75
50
25
0
Land degradation
Wild biodiversity loss
Agro-biodiversity loss
Water depletion
Water pollution
Soil nutrient depletion
Soil pollution
Pest resistance
GHG emissions (CH4)
GHG emissions (N20)
Air pollution (burning)
Storage chemicals
Post-harvest losses

Noteworthy Research Gaps

In Sub-Saharan Africa	In South Asia
❑ Little on agro-biodiversity loss, water depletion, air pollution, GHG emissions, and storage chemicals. ❑ Recent declines in sorghum/ millet publications across topics. ❑ Cassava important, but little published literature available for most environmental impacts. ❑ Biodiversity loss for maize and cassava, and water depletion, GHG emissions and air pollution for all crops merit more attention.	❑ Few publications on biodiversity and storage chemicals, and water depletion and GHG emissions research almost exclusively for rice. ❑ Cassava of some importance in the south but almost no research on environmental issues, especially soil nutrients and water depletion. ❑ Maize increasingly important; need more environmental impact research in areas such as water depletion. ❑ Also may need additional attention to biodiversity in intensive systems.

Good Practices to Reduce Negative Crop-Environment Interactions

Maize intercropped with legumes such as cowpea

Improved processing of cassava roots

Sustainable Productivity Growth

for key crops (and cropping systems)

Good Practices include:

- Crop choice & timing
- Abiotic & biotic stress tolerant varieties
- Rotations, intercrops & agroforestry
- Integrated nutrient management
- Water conservation & irrigation
- Integrated pest management
- Improved crop storage

Reduced Environment Constraints to Crop Production

Increased Environmental Services & Less Environmental Degradation

Sustainable Productivity Growth

for key crops (and cropping systems)

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- Integrated nutrient management
- Water conservation & irrigation
- Integrated pest management
- Improved crop storage

Reduced Environment Constraints to Crop Production

Reduced Impact of Cropping on Environment

Good Practices include:

- Good selection of ecology & fields
- Agroforestry/bush fallowing
- Minimal soil tillage
- Retention of residues
- Intercropping & rotation
- Some intensification
- Appropriate use of fertilizers & pesticides
- Better processing & storage

Increased Environmental Services & Less Environmental Degradation

Key Take-Aways

- Smallholder farmers grow many crops in complex, overlapping systems
- No silver bullet:
  - Environmental interventions are highly context-specific
- Research is uneven across regions, crops, and farming systems, and some gaps remain

Thank you

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