Universiteit Utrecht

Energy crops and Agroforestry Systems – Improved Land Use

International Conference 'Bioenergy for Sustainable Development in Africa – Lessons learnt from COMPETE'
Hilton Hotel, 24 – 25 November 2009, Brussels, Belgium

André Faaij, Edward Smeets,
Birka Wicke & Veronika Dornburg
Copernicus Institute - Utrecht University – The Netherlands

Copernicus Institute
Sustainable Development and Innovation Management

SIXTH FRAMEWORK PROGRAMME

COMPETE

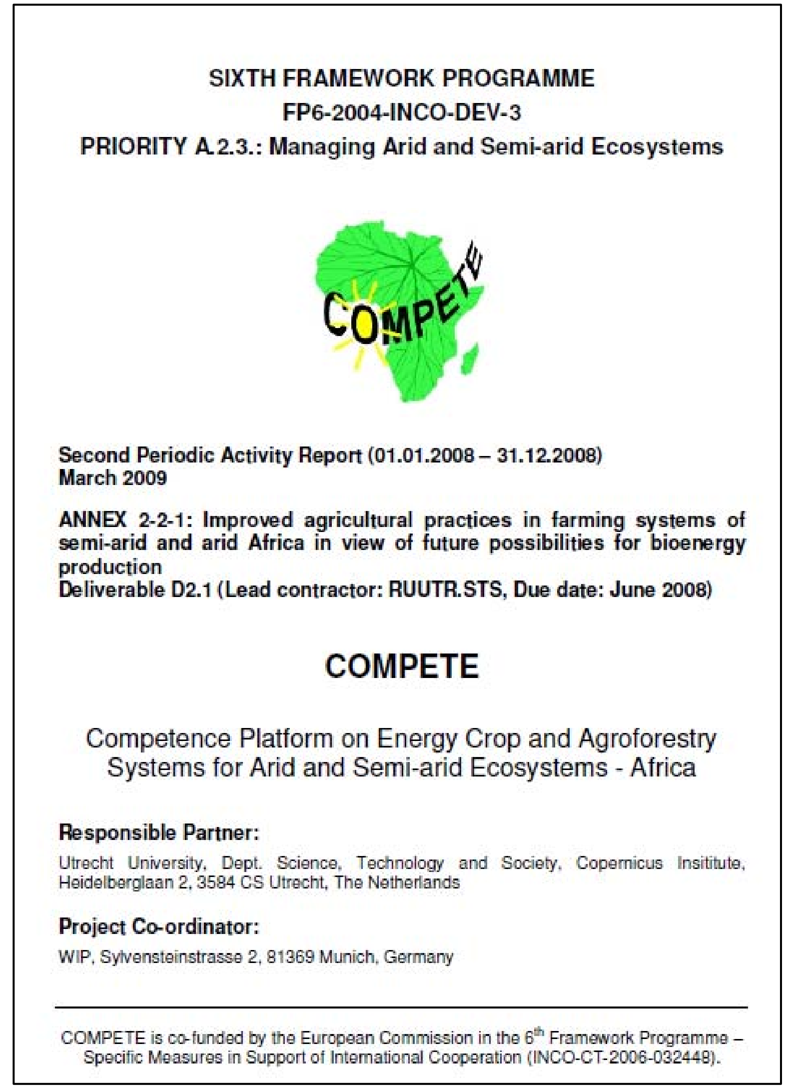
Objective

- To provide an overview of experiences and concepts for sustainable production (and use) of biomass for energy:
  - 1A Overview of present and improved agricultural practices
  - 1B Overview of present and improved biomass energy production systems, including environmental and social impacts
  - 2 Insight in biomass production potentials and contribution to energy supply, income and employment generation and ecological impacts in the South African region.

Present and improved agricultural practices (objective 1A)

D 2.1 March 2009 (48 p)

M. Cocchi, ETA, Italy
T. Dafrallah, ENDA-TM, Senegal
R. Diaz-Chavez, Imperial College, United Kingdom
V. Dornburg, Utrecht University, The Netherlands
A. Faaij, Utrecht University, The Netherlands
H. Hongo, Felisa, Ltd., Tanzania
K. Munyinda, University of Zambia/CEEEZ, Zambia
E. Sawe, TaTEDO, Tanzania
E. Smeets, Utrecht University, The Netherlands
J. Shuma, TaTEDO, Tanzania
I. Togola, MaliFolkeCenter, Mali
K. Ulsrud, Oslo University, Norway
F. D. Yamba, University of Zambia/ CEEEZ, Zambia



SIXTH FRAMEWORK PROGRAMME
FP6-2004-INCO-DEV-3
PRIORITY A.2.3.: Managing Arid and Semi-arid Ecosystems

COMPETE

Second Periodic Activity Report (01.01.2008 – 31.12.2008)
March 2009

ANNEX 2-2-1: Improved agricultural practices in farming systems of semi-arid and arid Africa in view of future possibilities for bioenergy production
Deliverable D2.1 (Lead contractor: RUUTR.STS, Due date: June 2008)

COMPETE

Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems - Africa

Responsible Partner:
Utrecht University, Dept. Science, Technology and Society, Copernicus Insititute, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands

Project Co-ordinator:
WIP, Sylvensteinstrasse 2, 81369 Munich, Germany

COMPETE is co-funded by the European Commission in the 6th Framework Programme – Specific Measures in Support of International Cooperation (INCO-CT-2006-032448).

Present and improved biomass energy production systems (objective 1B)

Universiteit Utrecht

D 2.2 & 2.3 June 2009 (89 p)

G. Austin, AGAMA, South Africa
M. Cocchi, ETA, Italy
T. Dafrallah, ENDA-TM, Senegal
R. Diaz-Chavez, Imperial College, United Kingdom
V. Dornburg, Utrecht University, The Netherlands
J. van Eijck, Utrecht University, The Netherlands
A. Faaij, Utrecht University, The Netherlands
M. Hoffmann, ESD, United Kingdom
F. Johnson, SEI, Sweden
S. Mutimba, ESD, Kenya
K. Munyinda, University of Zambia/ CEEEZ, Zambia
J. Robinson, Eco Ltd., United Kingdom
S. Senechal, EUBIA, Belgium
E. Smeets, Utrecht University, The Netherlands
A. Stepniczka, ABI, Austria
J. Suma, TaTEDO, Tanzania
F. Yamba, University of Zambia/ CEEEZ, Zambia
W. Wiskerke, Utrecht University, The Netherlands

SIXTH FRAMEWORK PROGRAMME FP6-2004-INCO-DEV-3
PRIORITY A.2.3.: Managing Arid and Semi-arid Ecosystems

COMPETE

Third Periodic Activity Report
(01.01.2009 – 31.12.2009)
December 2009

ANNEX 2-3-1. Traditional, improved and modern bioenergy systems for semi-arid and arid Africa
Deliverable D2.2 & D2.3: (Lead contractor: WIP, Due date: June 2009)

COMPETE

Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems - Africa

Responsible Partner / Work Package Leader:
Copernicus Institute, Utrecht University, Heidelberglaan 2, NL-3584 CS Utrecht, The Netherlands

Project Co-ordinator:
WIP, Sylvensteinstrasse 2, 81369 Munich, Germany

COMPETE is co-funded by the European Commission in the 6th Framework Programme Specific Measures in Support of International Cooperation (INCO-CT-2006-032448).

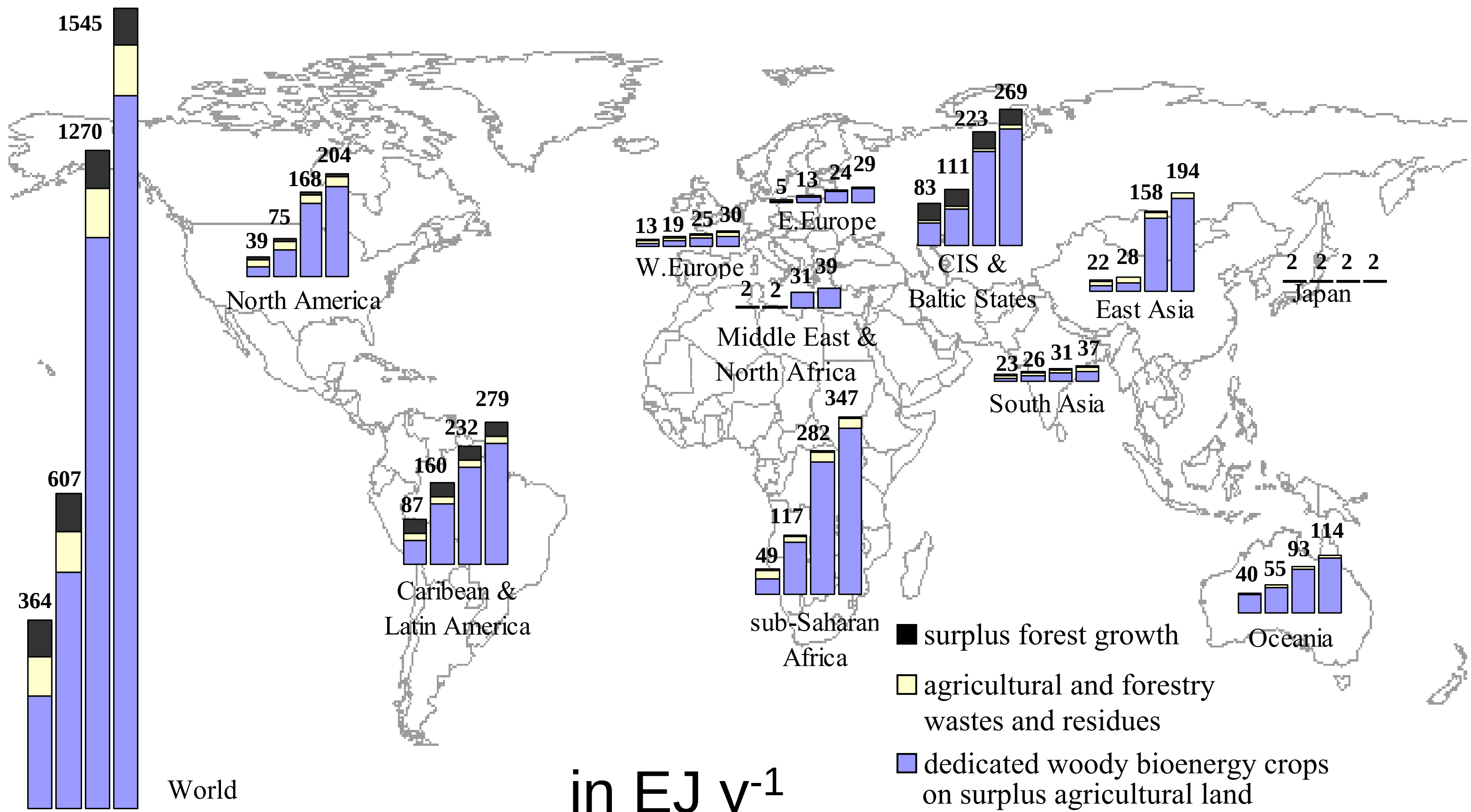
Present and improved agricultural practices

- Key targets for improvement
  - Increase use of fertilizers
  - Increase efficiency of the use of irrigation water
  - Increase use of machinery
  - Increase pest and disease management
  - Increase use of improved genetic crop varieties and livestock
  - Reduce post-harvest lossess

Present and improved agricultural practices - Technical bioenergy potentials in 2050

Universiteit Utrecht

Source: Smeets, Faaij 2007
Progress in Energy & Combustion Science



in EJ y^{-1}

Copernicus Institute
Sustainable Development and Innovation Management

Present and improved agricultural practices - Agroforestry

Soil nutrients and organic matter	Other effects soil	Others
Taking up nutrients released by rock weathering in deeper layers and recycling it tot the surface	Improvement of soil physical properties, e.g. structure, porosity, WHC, breaking up of indurated layers	Atmospheric input by trapping rainfall, dust and nutrients
Nitrogen fixation by leguminous and non-leguminous trees	Exudation of growth promoting substances	Wind effects: act as windbreaks and therefore as anti-erosive agents
Production of a range of plant litter of different quality	Beneficial effects on soil flora and fauna	Capture industrial aerosols and therefore purifies air and reduces air pollution
Increases of soil organic matter carbon fixation in photosynthesis and transfer via litter and root decay	Modification of soil temperature extremes	Rehumidify air streams
Prevention of soil erosion and loss of organic matter and nutrients	Reduction of soil acidity through addition of plant litter	Control air temperature by evaporative cooling
	Reduction of salinity or sodicity	Noise reduction

Present and improved agricultural practices - Agroforestry in Tanzania

Agroforestry system that consists of crops, trees and livestock to enhance fuelwood and fodder production and to improve soil fertility in Shinyanga in Northern Tanzania

Tree establishment and intercropping phase

Tree fallow phase

Cropping phase

New tree fallow phase

Present and improved traditional bioenergy systems

- Use of traditional fuelwood leads to:
  - Deforestation
  - Carbon emissions
  - Gender issues
  - Indoor air pollution (10 million premature deaths by 2030 !)
  - High labour / time input
  - Inefficient use
  - Accidents

Table: The efficiency of charcoal kilns

Kiln type	Percentage recovery oven dried wood	Percentage recovery air dried wood
Casamance earth kiln	31	27
Metal channel earth kiln	29	25
Modified metal channel kiln	25	21
Earth mound kiln (control)	25	21
Pit kiln	15	13

Remarkable high efficiency of traditional earth mound kilns!

Present and improved traditional bioenergy systems

Universiteit Utrecht

Key drivers for improved cooking stoves and charcoal kilns:

- Combustion efficiency
- Heat transfer efficiency
- Safety
- Costs
- Durability

From left to right: the BP Oorja Stove, the Philips Wood Stove and the Kuni Mbili firewood stove

Energy carrier	Stove type	Efficiency	Cost (US$)	Lifetime	Cost of heat (US$/GJ$_H$)
Wood	3-stone stove	7%	free	-	28
Wood	(Improved) mud stove	22.5%	1.43	2 months	9
Wood	(Improved) burned brick stove	29%	33.20	5 years	7
Charcoal	Traditional stove	16.5%	1.66	3 years	35 Legal 21 Illegal
Charcoal	Improved stove	45%	8.00	3 years	13 Legal 8 Illegal
Kerosene	Kerosene stove	38%	12.45	3 years	95
Electricity	Electricity stove	68%	49.80	5 years	42

The performace of traditional and improved cooking stoves

COMPETE

Present and improved modern bioenergy systems

Universiteit Utrecht

- Biogas from residues and waste
- Heat and electricity from institutional stoves and large scale boilers from residues and waste or dedicated woody crops and grassess
- Pure plant oil from jatropha and other oil crops
- Ethanol from cassava, sugar cane, sweet sorgum

Construction of a 20 m3 biogas digester for processing sewage wastewater, food scraps and chicken litter

Socio-economic impacts of bioenergy systems

4 issues are addressed:

- Best practice on stakeholder involvement
- Women participation in management levels and decision make processes
- Indigenous people participation in management levels and in decision make processes
- Competitiveness of energy crops with respect to other (food) crops

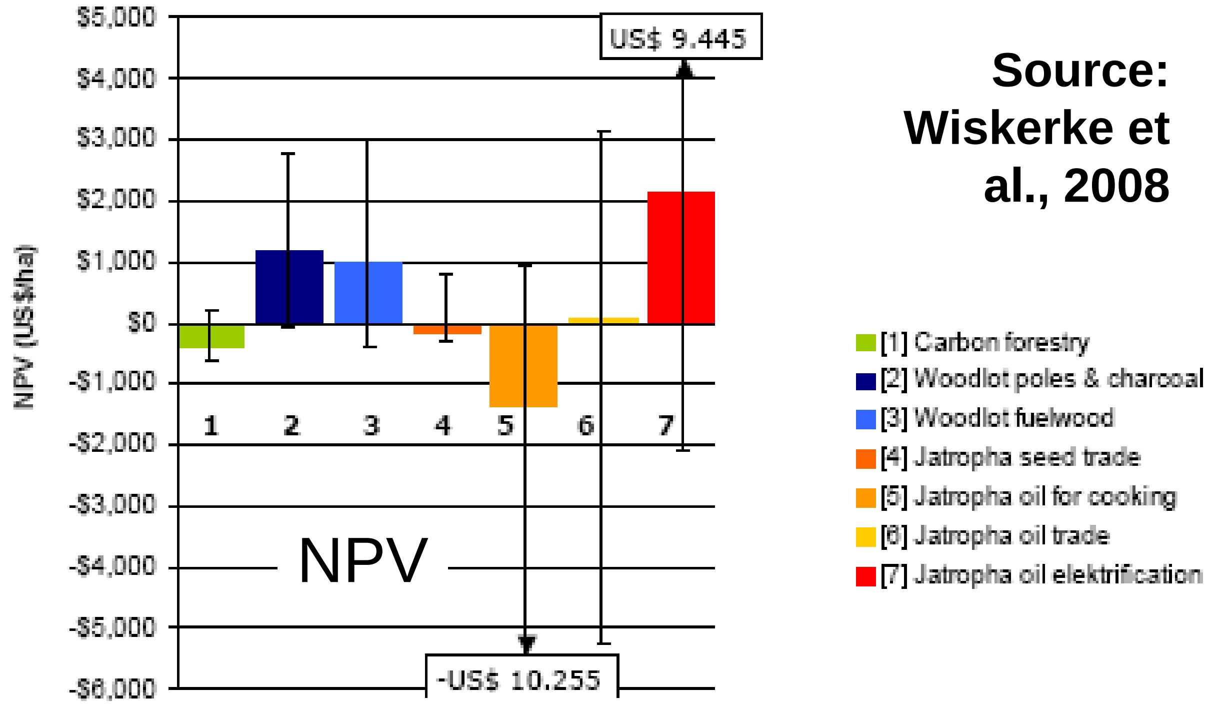
Socio-economic impacts of bioenergy systems in Tanzania

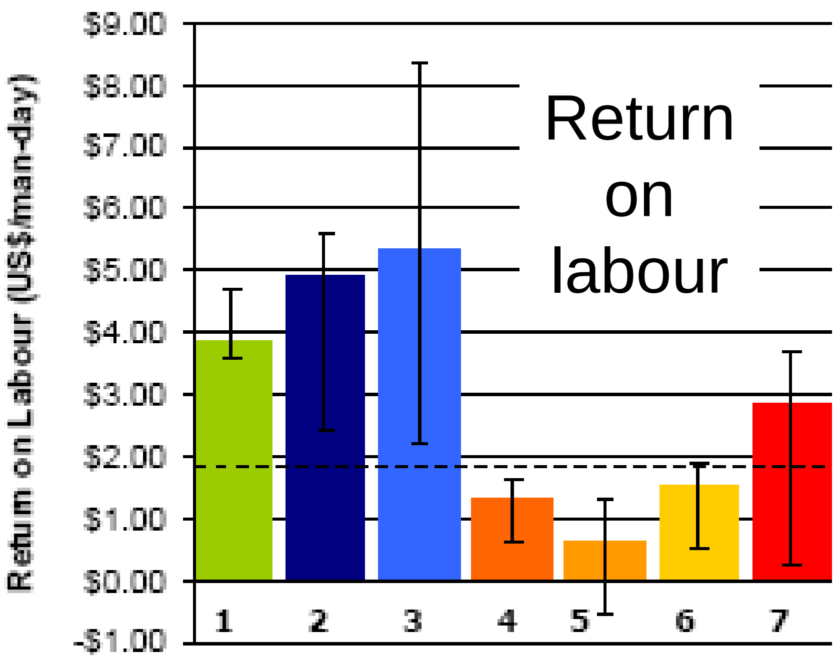
- The socio-economic impacts of three biomass energy supply systems for rural households in Shinyanga (TZ):
  - Small-scale forestation and fuelwood project for carbon sequestration under the Clean Development Mechanism (CDM)
  - A short rotation woodlot for the production of fuelwood or charcoal, optionally with intercropping.
  - A jatropha curcas plantation for cooking fuel, export or diesel substitute for off-grid household electrification or for soap production.
- Parameters:
  - Net present value
  - Return on labour
  - Cost of energy

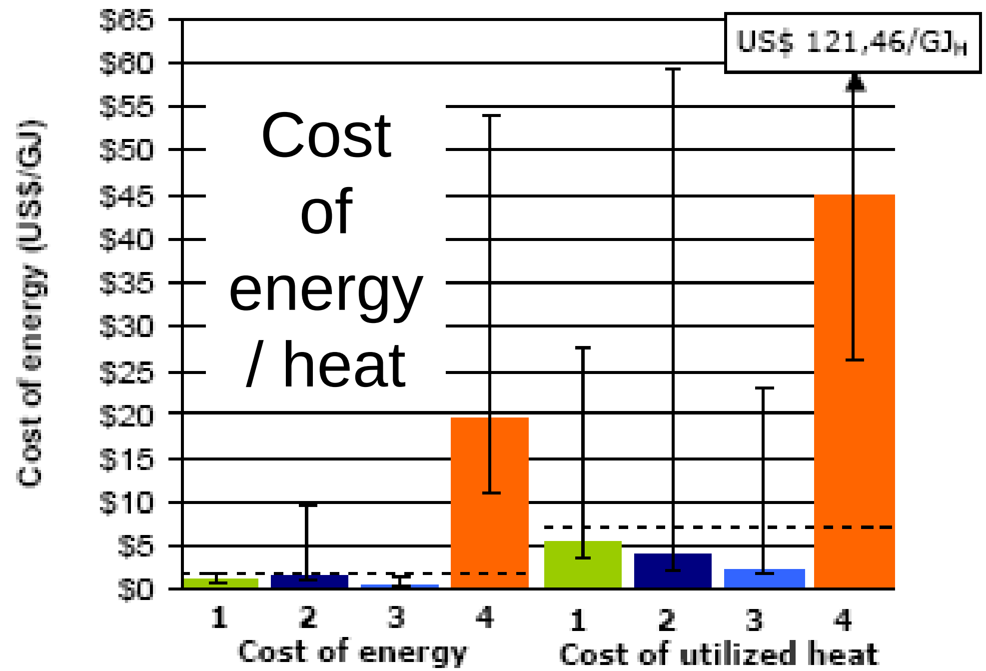
Source: Wiskerke et al., 2008

Socio-economic impacts of bioenergy systems in Tanzania

Source: Wiskerke et al., 2008

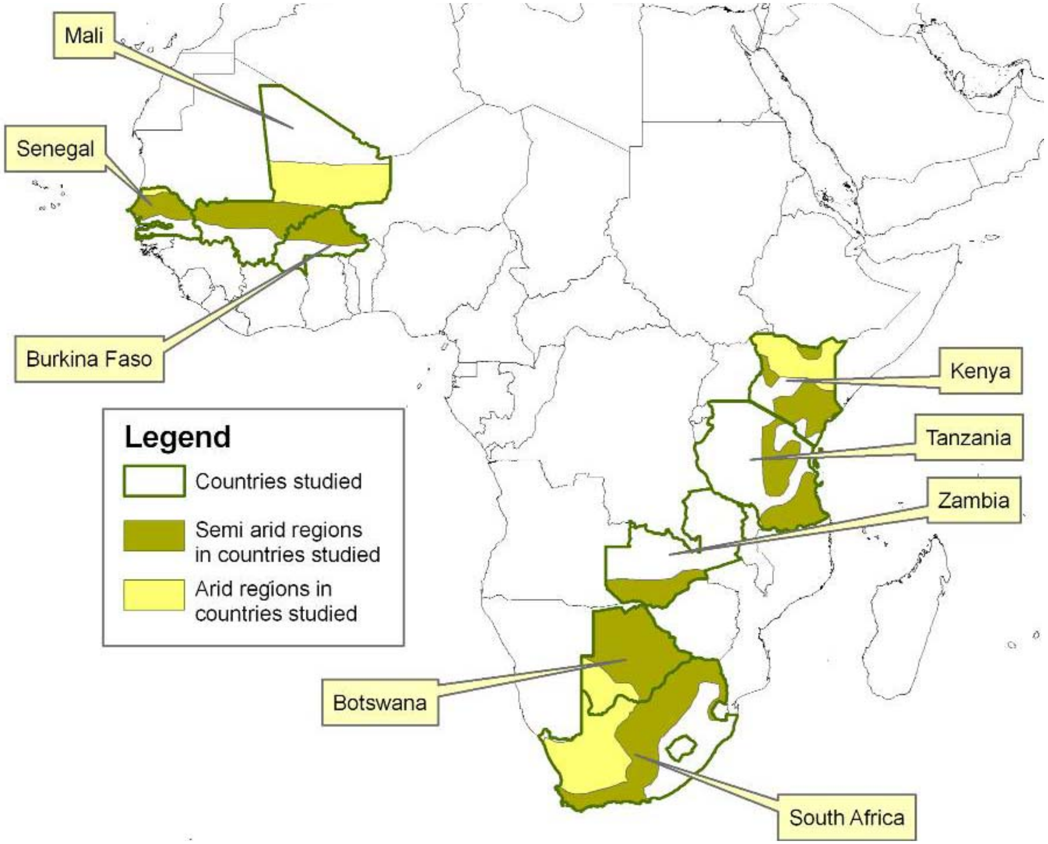






Insight in biomass production potentials and contribution to energy supply, income and employment generation and ecological impacts in the South African region (objective 2)

- Three systems (ethanol cassava, jatropha oil, woody crops fuelwood)
- Technical potential
- Economic potential
- Net present value
- Employment generation
- GHG emissions
- Other env. impacts (soil nutrient removal, water, biodiversity)

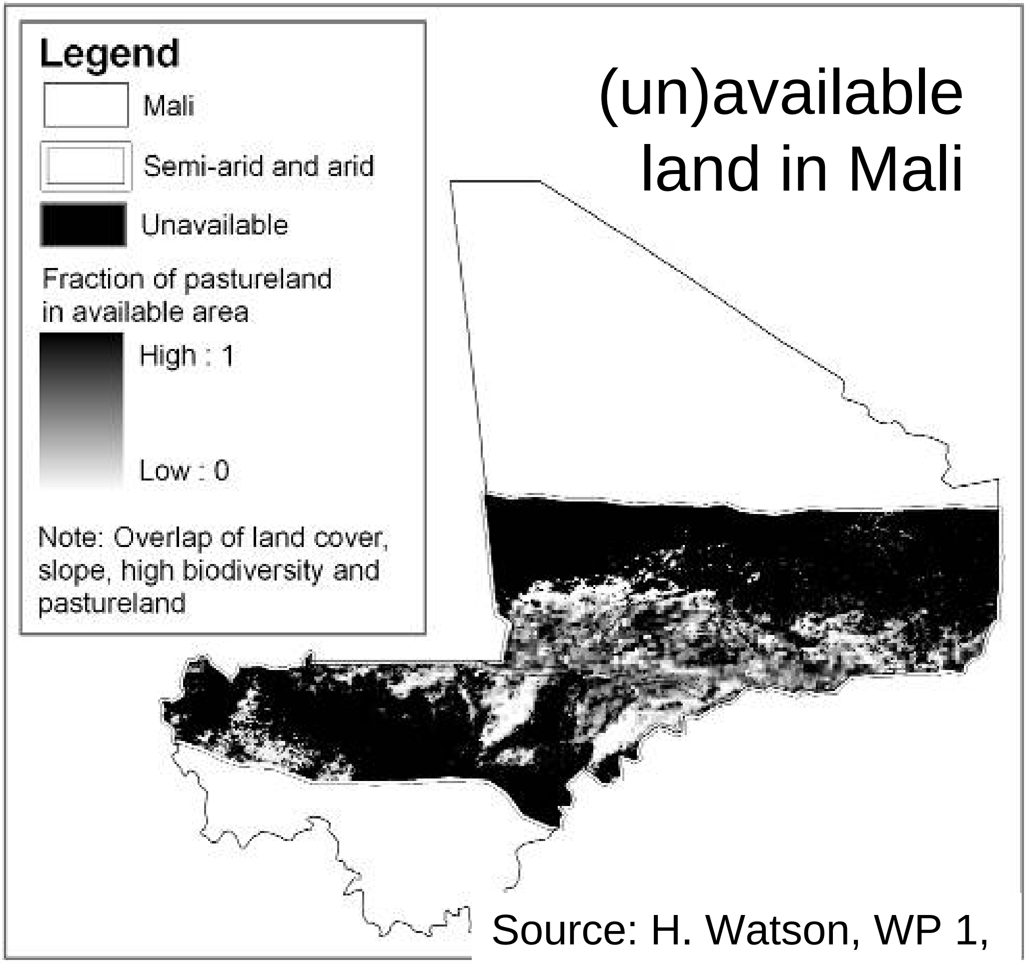


Technical biomass production potentials in Southern Africa

– Technical and economic potentials, excl.:

- Protected areas
- Closed canopy forests
- Cropland
- Pastures
- Unsuitable areas (cities, bare rock, deserts, …)
- High biodiversity areas and biodiversity hotspots
- Steep slopes (>8%)

– Yields are estimated using crop growth models and values from literature



Source: H. Watson, WP 1, plus additional analysis

Technical biomass production potentials in Southern Africa

In Mha Areas	Botswana	Burkina Faso	Kenya	Mali	Senegal	South Africa	Tanzania	Zambia
Total area	**58.0**	**27.3**	**58.6**	**125.7**	**19.7**	**122.2**	**94.6**	**75.5**
- Semi-arid area	45.4	14.5	22.8	24.7	9.8	52.4	31.8	16.1
- Arid area	12.5	0.5	23.3	39.5	1.5	37.9	0.0	0.0
- Non arid/semi-arid	0.0	12.3	12.4	61.4	8.3	31.9	62.7	59.4
Excluded area	**47.2**	**14.8**	**41.8**	**59.4**	**10.9**	**83.6**	**30.7**	**15.3**
- Unsuitable								
-- Cities, bare rock,..	0.7	0.0	0.8	21.8	0.2	1.0	0.3	0.2
-- Steep slopes (≥8%)	6.1	3.1	19.6	8.5	0.8	63.7	14.7	5.1
- High biodiversity								
-- Protected areas	18.7	2.0	3.2	2.7	2.8	5.8	6.5	5.3
-- Biodiversity hotspots	0.0	0.0	11.6	0.0	0.0	18.2	6.1	0.0
-- Closed canopy forest and wetlands	2.9	0.0	2.3	0.0	0.0	7.3	11.6	4.5
- Agricultural land								
-- Cropland	4.2	9.0	2.7	14.5	7.1	14.2	4.7	2.4
--Pastureland	21.7	3.2	15.9	20.2	3.1	48.5	13.4	5.3
Available area)	**10.7**	**0.2**	**4.3**	**4.8**	**0.5**	**6.6**	**1.1**	**0.7**
- Semi-arid	6.2	0.2	2.5	1.3	0.3	2.3	1.1	0.7
- Arid area	4.6	0.0	1.8	3.5	0.2	4.3	0.0	0.0

Technical biomass production potentials in Southern Africa

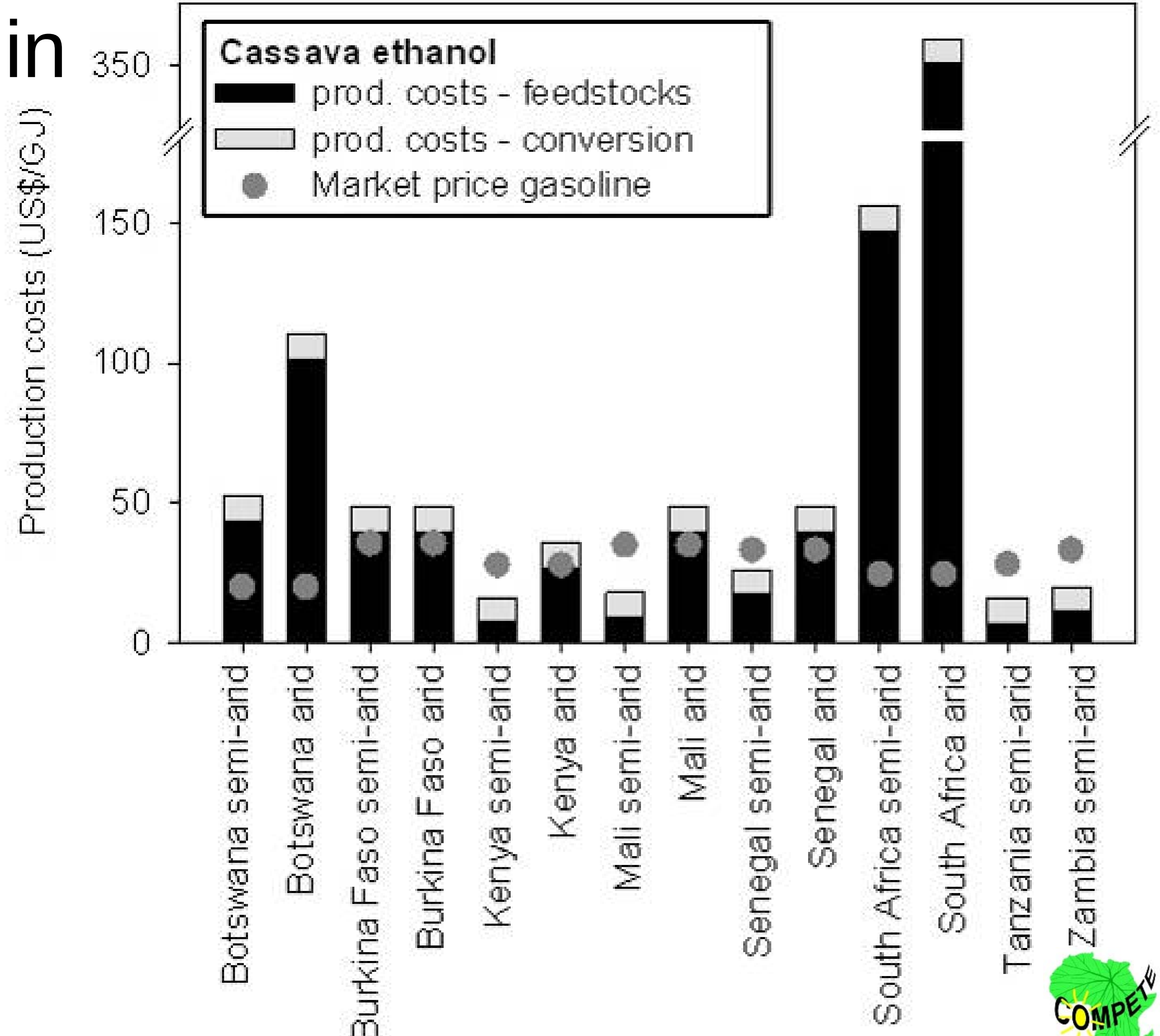
Universiteit Utrecht

In PJ y^{-1} Potentials	Bots-wana	Burkina Faso	Kenya	Mali	Senegal	South Africa	Tanza-nia	Zambia
Cassava ethanol	**123**	**2**	**82**	**69**	**6**	**62**	**35**	**14**
- arid	29	0	12	22	1	27	0	0
- semi-arid	94	2	70	47	5	35	35	14
Jatropha oil	**208**	**6**	**83**	**71**	**10**	**105**[a]	**29**	**19**
- arid	47	0	19	36	2	45	0	0
- semi-arid	160	6	64	34	8	60	29	19
Fuelwood	**743**	**49**	**902**	**389**	**70**	**565**	**293**	**144**
- arid	57	0	335	173	26	112	0	0
- semi-arid	687	48	567	216	45	453	293	144
Final consumption of energy 2006	**7**	**No data**	**58**	**No data**	**8**	**308**	**74**	**28**
- coal and peat	1		0		1	70	0	0
- petroleum products	3		14		4	95	6	3
- gas	0		0		0	11	0	0
- combustible renewables & waste	2		41		3	49	66	21
- electricity	1		2		1	83	1	3

High potentials compared to domestic energy consumption !

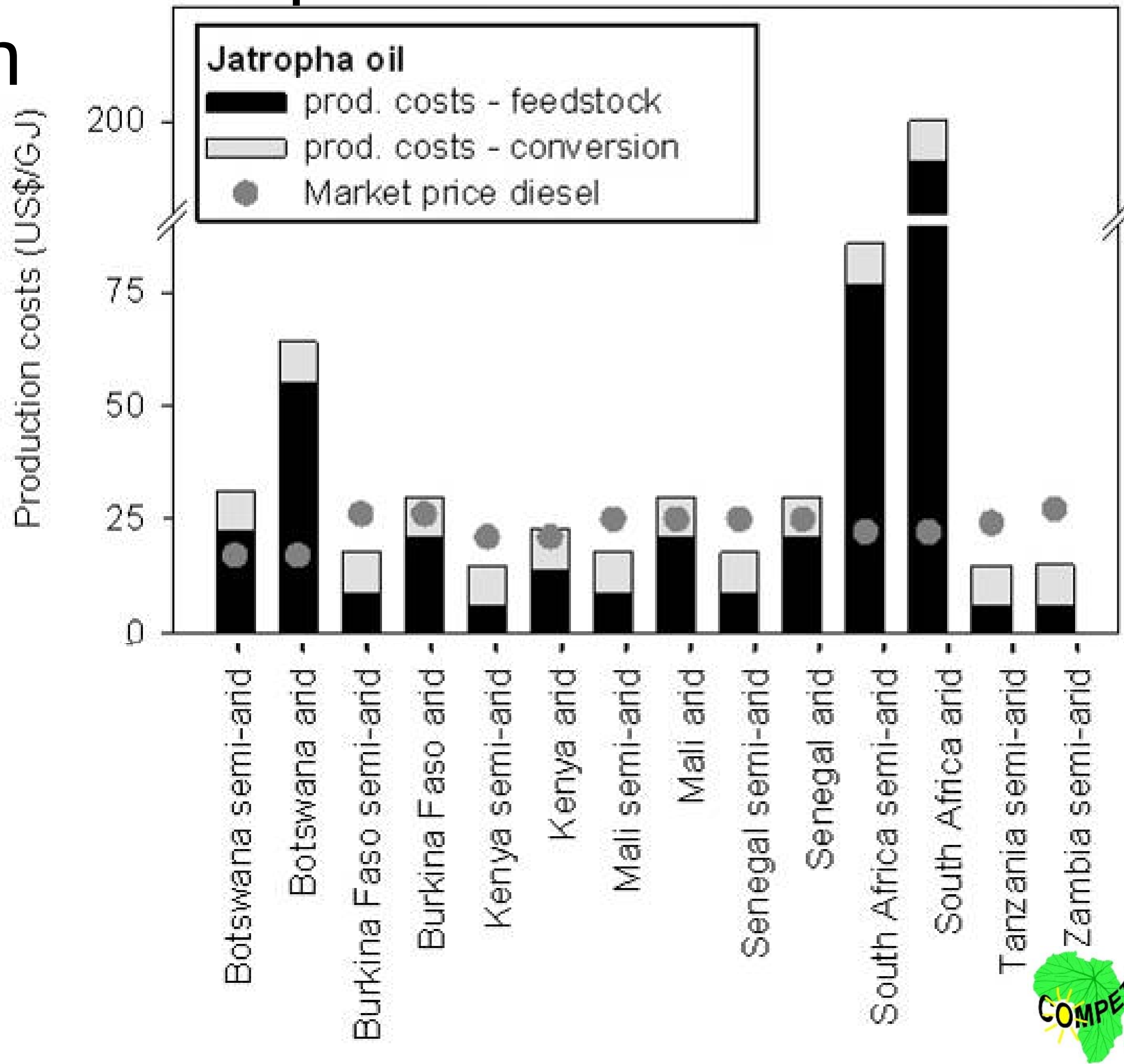
COMPETE

Economic biomass production potentials in Southern Africa

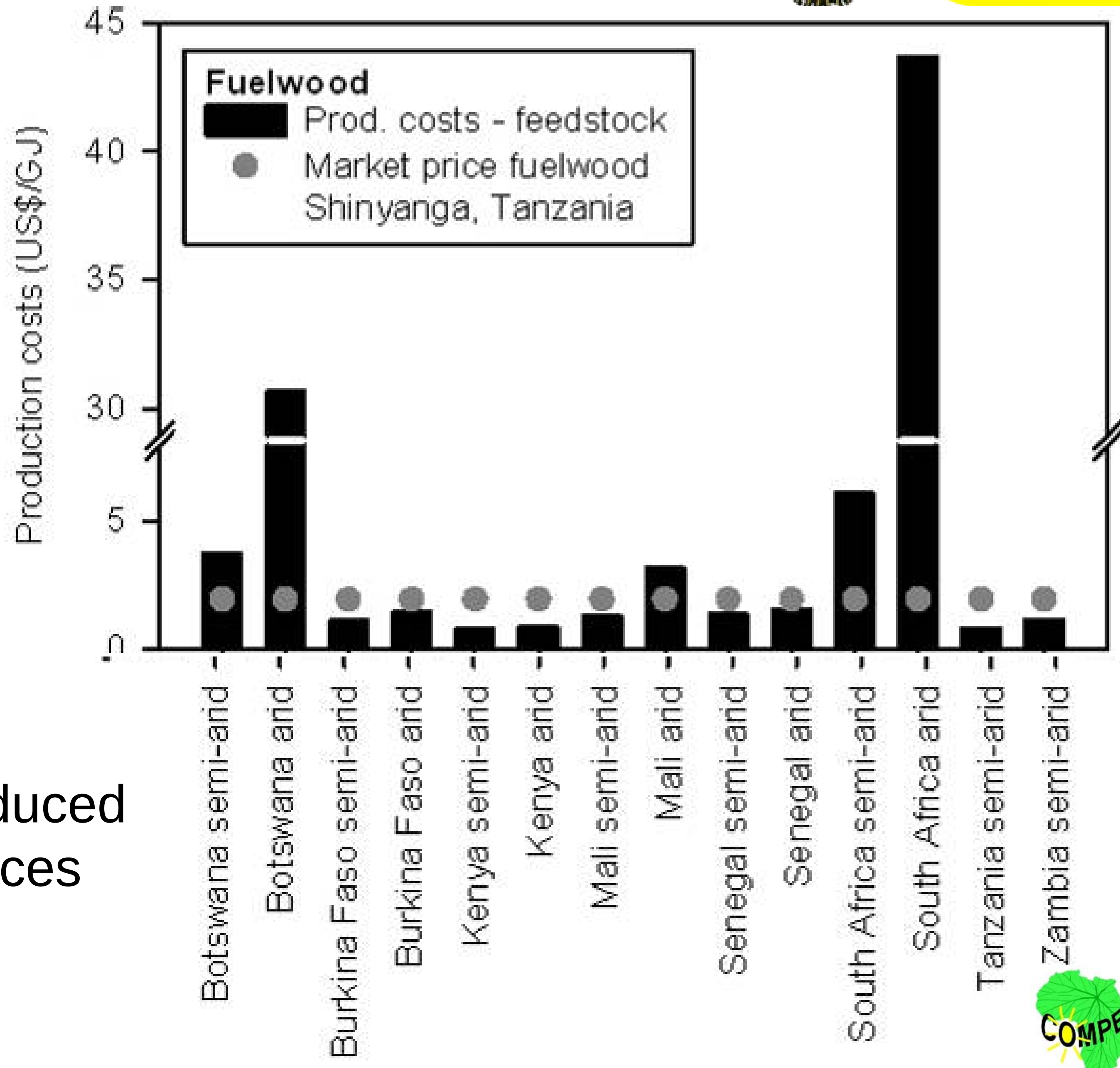


Costs are estimated using values from literature

Economic biomass production potentials in Southern Africa



Economic biomass production potentials Southern Africa



Fuelwood can Potentiall be produced at competitive prices

Socio-economic and environmental performance

Parameter	Units	Cassava	Jatropha	Woody crops
Technical potential	PJ y^{-1}	1251	1621	10929
Production costs	€ t^{-1} product	16 – 40	23 – 81	7 – 21
Production costs	€ l^{-1} eth/oil	0.4	0.3 – 0.4	n/a
NPV	€ t^{-1}	2 – 170	-67	43 – 72
Labor generation	hours ha^{-1}	901	1376	177
GHG emissions	g CO2-eq MJ^{-1}	75	26	9
GHG emission	% reduction	8	64	-

Some concluding remarks

- Large potential to improve agricultural production systems in Africa (agroforestry!)
- Large potential to improve traditional biomass energy systems (stoves and charcoal kilns)
- Potentially promising biomass systems are:
  - Pure plant oil for domestic use or for export
  - Ethanol from cassava, sugar cane or sweet sorghum
  - Biogas from residues and waste
  - Second generation biofuels from lignocellulose biomass
  - Electricity and heat from lignocellulose biomass
  - Heat from lignocellulose biomass & improved traditional biomass energy systems ! ! !
- Large variation in socio-economic and natural conditions and production systems; more local analyses and data are crucial

Universiteit Utrecht

Thanks for your attention

AND

for your contributions to WP 2 !

SIXTH FRAMEWORK PROGRAMME

André Faaij

a.p.c.faaij@uu.nl

COMPETE

http://www.compete-bioafrica.net/