

TRADE-OFFS IN THE DESIGN OF SUSTAINABLE CROPPING SYSTEMS AT A REGIONAL LEVEL: A CASE STUDY ON THE NORTH CHINA PLAIN

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SUPPLEMENTARY MATERIALS

Table S1 Cropping systems included in the analysis

Cropping system	Duration (years)
Alfalfa	1
Continuous cotton	1
Continuous spring maize	1
Continuous spring peanut, rainfed	1
Continuous spring soybean, rainfed	1
Continuous summer maize	1
Continuous winter wheat	1
Ryegrass + cotton → peanut → WM	3
Ryegrass → Sorghum	1
Ryegrass + cotton	1
Ryegrass + sorghum → WM	2
Ryegrass + spring maize	1
Spinach → spring maize	1
Spring cotton → WM	2
Spring maize, rainfed	1
Spring maize → summer maize	1
Spring maize → WM	2
Spring peanut → WM	2
Spring soybean → WM	2
Sweet potato → cotton → sweet potato → WM	4
Sweet potato → WM	2
Switchgrass	1
Winter wheat → summer cotton → spring maize	1
Winter wheat → summer cotton	1
Winter wheat → summer millet	1
Winter wheat → summer peanut	1
Winter wheat → summer soybean	1
Winter wheat → sweet potato	1
WM	1
WM, rainfed	1

Note: Symbols '+': combined with; '→': followed by. WM: winter wheat → summer maize.

Table S2 Decision variables, constraints and objectives used in the multi-objective optimization

Objectives	Direction of optimization	
Economic revenues (R _Y)	Maximize	
Decline of the groundwater table (NWD)	Minimize	
Nutritional system yield of livestock products (NSY _{LP})	Maximize	
Nutritional system yield of dietary energy NSY _{DE})	Maximize	
Nutritional system yield of vitamin C (NSY _{VC})	Maximize	
Constraints	Minimum	Maximum
Cropped area (ha)	98	100
Deviation in energy balance for livestock feeding (%)	-5	5
Decision variables	Minimum	Maximum
Alfalfa area (ha)	0	100
Continuous cotton area (ha)	0	100
Continuous spring maize area (ha)	0	100
Continuous spring peanut, rainfed area (ha)	0	100
Continuous spring soybean, rainfed area (ha)	0	100
Continuous summer maize area (ha)	0	100
Continuous winter wheat area (ha)	0	100
Ryegrass + cotton → peanut → WM area (ha)	0	100
Ryegrass → Sorghum area (ha)	0	100
Ryegrass + cotton area (ha)	0	100
Ryegrass + sorghum → WM area (ha)	0	100
Ryegrass + spring maize area (ha)	0	100
Spinach → spring maize area (ha)	0	100
Spring cotton → WM area (ha)	0	100
Spring maize, rainfed area (ha)	0	100
Spring maize → summer maize area (ha)	0	100
Spring maize → WM area (ha)	0	100
Spring peanut → WM area (ha)	0	100
Spring soybean → WM area (ha)	0	100
Sweet potato → cotton → sweet potato → WM area (ha)	0	100
Sweet potato → WM area (ha)	0	100
Switchgrass area (ha)	0	100
Winter wheat → summer cotton → spring maize area (ha)	0	100
Winter wheat → summer cotton area (ha)	0	100
Winter wheat → summer millet area (ha)	0	100
Winter wheat → summer peanut area (ha)	0	100
Winter wheat → summer soybean area (ha)	0	100
Winter wheat → sweet potato area (ha)	0	100
WM area (ha)	0	100
WM, rainfed area (ha)	0	100
Fraction of Sweet potato fed to animals	0	0.7
Fraction of Sweet Potato 1 fed to animals	0	0.7
Fraction of Sweet Potato 2 fed to animals	0	0.7
Fraction of Maize grain fed to animals	0	0.25
Fraction of Soybean fed to animals	0	0.25
Fraction of Maize grain fed to animals	0	0.25
Fraction of other animal feeds (maize and soybean grain fed to animals (23 instances related to various cropping systems)	0	0.25
Livestock unit production (number of consumer units that can be fed with livestock products per unit of area (km ²))	500	10000

Note: Symbols '+': combined with; '→': followed by. WM: winter wheat → summer maize.