

## Appendix 1

Figure A1.1: Second-tier SESF components for provisioning and appropriating genetic diversity in German winter wheat

Pre-breeding system (PB-RS) †		Governmental resource system (G-RS) †		Breeding firms resource systems (BF-RS) †		Governance system (GS) †		
PB-RS1	Public and private seed sector	G-RS 1	Public sector	BF-RS1	Seed sector	GS1	Breeders rights	
PB-RS2	No clear boundaries	G-RS 2	Clear boundaries	BF-RS2	Heterogenous by firm	GS2	Germany as part of EU	
PB-RS3	Big	G-RS 3	Testing sites	BF-RS3 †	Heterogenous size of nurseries	GS3	All plant breeders	
PB-RS4	Nurseries and screening facilities	G-RS 4	Nurseries and facilities for evaluation of trials	BF-RS4 †	Facilities for phenotypic and genotypic evaluation	GS4	Democratic	
PB-RS5	-	G-RS 5	All Varieties on DVL	Lines in VCU testing	BF-RS5	Number of lines submitted for approval	GS5	Legislative branch of government (EU-level/National legislation); Lobbying organizations
PB-RS7	-	G-RS 7	-	-	BF-RS7	Fairly predictable	GS6	Operational-choice rules and collective-choice rules under constitutional-choice rules
PB-RS8	Medium	G-RS 8	Not existent	Not existent	BF-RS8	Medium	GS7	Private and common property side by side
PB-RS9	Globally spreadout	G-RS 9	-	6 trial sites over Germany	BF-RS9 †	Heterogenous by firm locations in Germany and worldwide	GS8	Multiple norms and strategies within community
Pre-breeding Material (PB-RU) †		DVL Varieties (G-RU)		Breeding Firms' Systems (BF-RU) †		Breeders (B-A) †		
		Approved (G-RUa) †	Pre-approved (G-RUb) †					
PB-RU1	-	G-RU1	Mobile	Immobile with exceptions	BF-RU1	Immobile with exceptions	B-A1	19 winter wheat breeders
PB-RU2	-	G-RU2	Number of new varieties per year	Number of submitted lines per year	BF-RU2	Heterogenous per firm	B-A2 †	Heterogenous depending on firm size
PB-RU3 †	High	G-RU3 †	Low - medium	High	BF-RU3 †	High	B-A3	Experiences with own material and varieties important for usage
PB-RU4	Very high; invaluable	G-RU4	-	-	BF-RU4	Heterogenous per variety	B-A4	Heterogenous locations in Germany and worldwide
PB-RU5	Heterogenous	G-RU5	All varieties in DVL	Number of lines in VCU testing	BF-RU5	Heterogenous per firm	B-A5	Entrepreneurial
PB-RU6	Heterogenous	G-RU6 †	Name of variety; DUS results	VCU testing results of lines submitted	BF-RU6	Labels applied within nursery	B-A6 †	Partially very strong trust & reciprocity relationships
PB-RU7b	Programs in Germany & worldwide	G-RU7b	Spread over Germany	VCU testing sites in Germany	BF-RU7b †	Material within nurseries	B-A7	Heterogenous mental models per breeder determined by incomplete information
PB-RU7a	Since 1960's	G-RU7a	Number of varieties approved each year	Three years of VCU testing	BF-RU7a	Each year resown according to plan	B-A8	Very high resource dependent
							B-A9 †	Heterogenous per firm
Action situations appropriation and provision of genetic diversity								
Interactions (GD-I)				Outcomes (GD-O)				
GD-I1 †	Levels of usage of material			GD-O1 †	Efficient use of genetic traits			
GD-I2a †	Information sharing			GD-O2 †	Sustained German gene pool			
GD-I2b †	Material sharing			GD-O3	-			
GD-I2c †	Nursery space sharing							
GD-I5 †	Investments in joined R&D projects							
GD-I7 / GD-I8 †	Networking - common activities in R&D projects							

Source: Own depiction of second-tier variables adopted from McGinnis and Ostrom (2014), with alternative variables for the governance system. As there are multiple resource systems with resource units and actor groups these variables are preceded by an abbreviation for the respective group. Individual variables not found relevant to the case are tagged with '-'. VCU denotes value of cultivation and use testing. DVL means the Descriptive Variety List. DUS denotes distinctiveness, use and stability testing. Relevant sources for the included variables were mainly interviews 1, 2, 3, 7, 8, 10, 12-15, 17-20, 22, 24-30, and 32; see list appendix 2 table 1. † marks those variables used in the main text.

Governmental resource system (G-RS)		Breeding firms resource systems (BF-RS)		Multiplication system (M-RS)		Governance system (GS)				
G-RS1	Public sector	BF-RS1	Seed sector	PB-RS1	Seed sector	GS1 †	Breeders rights and Seed regulations			
G-RS2	Clear boundaries	BF-RS2	Heterogenous depending on firm	PB-RS2	Clear boundaries	GS2	Germany			
G-RS3	Testing sites and respective sites for testing available	BF-RS3	Heterogenous size of nurseries	PB-RS3	Size of multiplier	GS3 †	All plant breeders and multiplication organisations, multiplying farmers and certification organisations for seed			
G-RS4	Nurseries and facilities for evaluation of trials	BF-RS4	Heterogenous facilities for phenotypic and genotypic evaluation	PB-RS4	Fields multiplication	GS4	Democratic			
G-RS5	All varieties on DVL	Lines in VCU testing	BF-RS5	Number of lines submitted for approval	PB-RS5	Propagation area for the crop	GS5	Legislative branch of government		
G-RS7	Predictable variety performance		BF-RS7	Fairly predictable	PB-RS7	Heterogenous per variety	GS6	Operational-choice rules and constitutional-choice rules		
G-RS8	-	-	BF-RS8	Minimal	PB-RS8	Medium	GS7 †	Private property system		
G-RS9 †	State variety trials in different regions	6 trial sites over Germany	BF-RS9	Heterogenous locations in Germany and worldwide	PB-RS9	Heterogenous within regions	GS8	Multiple norms and strategies		
DVL Varieties (G-RU)		Breeding Firms' Systems (BF-RU)		Multiplied Material (M-RU)		Breeders (B-A)		Multipliers (M-A)		
Approved (G-RUa) †	Pre-approved (G-RUb) †									
G-RU1	Mobile	-	BF-RU1	Mobile	M-RU1	Mobile	B-A1	19 Winter wheat breeders	M-A1	Oligopoly to polypoly
G-RU2	Number of new varieties per year	Number of submitted lines per year	BF-RU2	Heterogenous per firm	M-RU2 †	For winter wheat the multiplication factor is 1:40	B-A2	Heterogenous depending on firm size	M-A2	Heterogenous depending on firm size and type
G-RU3	-	-	BF-RU3	-	M-RU3	-	B-A3	Experiences with own material and varieties important for usage	M-A3	Experiences with kinds of varieties sold
G-RU4	Predictable if in state trials		BF-RU4	Heterogenous per variety	M-RU4	Heterogenous per variety	B-A4	-	M-A4	Located in different regions
G-RU5	All varieties in DVL	Number of lines in VCU testing	BF-RU5	Heterogenous per firm	M-RU5	Heterogenous per multiplier and region	B-A5	Entrepreneurial	M-A5	Entrepreneurial
G-RU6	Name of variety & DUS results	VCU testing results of lines submitted	BF-RU6	Variety names applied to lines	PB-RU6	Variety names; VCU qualities	B-A6	-	M-A6	-
G-RU7b	-	VCU testing sites in Germany	BF-RU7b	-	M-RU7b	-	B-A7	Heterogenous mental models per breeder determined by incomplete information	M-A7	Mental models of SES and heuristics for devising multiplication areas
G-RU7a	Varieties approved each year	Three years of VCU testing	BF-RU7a	-	M-RU7a	Propagation each year	B-A8	High resource dependence	M-A8	High resource dependence
							B-A9	-	M-A9	-
Action situations for providing varietal diversity										
Interactions (PV-I)					Outcomes (PV-O)					
PV-I1 †	Levels of usage of varieties in propagation				PV-O1 †	Supply of diverse varieties fitting farmers preferences				
PV-I2a	Public provision of information on trial results				PV-O2 †	Ecological Performance – outcomes of VCU and FSV trials in different regarding yield and other qualities of a variety				
PV-I3	Heuristic deliberation of multipliers				PV-O3	-				
PV-I5 †	Investment in promising varieties									
PV-I10	Multipliers evaluate VCU and state trials results; are being quality checked									

Figure A1.2: Second-tier SESF components for provisioning varietal diversity in German winter wheat

Source: Own depiction of second-tier variables adopted from McGinnis and Ostrom (2014), with alternative variables for the governance system. As there are multiple resource systems with resource units and actor groups these variables are preceded by an abbreviation for the respective group. Individual variables not found relevant to the case are tagged with '-'. Relevant sources for the included variables were mainly interviews 1, 2, 3, 4, 6, 8, 9, 14, 21, 23, and 33; see list appendix 2 table 1. † marks those variables used in the main text.

	Farming system (F-RS)	Multiplication and retailing system (M-RS)	Governance system (GS)
F-RS1	Agricultural sector/ wheat cropping	M-RS1	Seed sector
F-RS2	Per farm clear boundaries	M-RS2	Clear boundaries
F-RS3	Heterogenous per farm	M-RS3	Heterogenous
F-RS4	Fields and grain storage facilities	M-RS4	Fields multiplication, storage facilities for seed
F-RS5	Harvest per hectare	PB-RS5	Heterogenous per propagation area for the crop/variety
F-RS7	Dependent on biotic and abiotic factors & variety	PB-RS7	Heterogenous per variety
F-RS8	Usually available	PB-RS8	High
F-RS9	Spread throughout Germany	PB-RS9	Heterogenous within regions
GS1 †			Seed regulations
GS2			Germany
GS3 †			Multiplication organizations, multiplying farmers and certification organizations for seed, all agricultural retailers
GS4			Democratic
GS5			Legislative branch of government
GS6			Operational-choice rules and constitutional-choice rules
GS7 †			Private property system
GS8			Multiple norms and strategies

Figure A1.3: Second-tier SESF components appropriating varietal diversity in German winter wheat

	Seed (F-RU)	Multipled material (M-RU)	Farmers (F-A)	Multipliers and retailers (M-A)
F-RU1	Mobile	M-RU1	Mobile	F-A1 Polypoly M-A1 Oligopoly
F-RU2	1:40 reproduction coefficient	M-RU2	Heterogenous per variety	F-A2 Heterogenous depending on firm size M-A2 Heterogenous depending on firm size and type
F-RU3	-	M-RU3	-	F-A3 Experiences with varieties M-A3 -
F-RU4	Heterogenous per farm (EU avg 50€/ha)	M-RU4	Heterogenous per variety	F-A4 Spread over different regions with various density M-A4 Located in different regions
F-RU5	-	M-RU5	Heterogenous per multiplier and region	F-A5 Entrepreneurial M-A5 Entrepreneurial
F-RU6	Heterogenous attributes per variety and per field	M-RU6	Variety names; public trial results	F-A6 - M-A6 -
F-RU7b	Varieties in farmers fields	M-RU7b	Multipliers fields within regions; local storage facilities of retailers	F-A7 Heterogenous mental models per farmers determined by different heuristics and social networks M-A7 Mental models of SES and heuristics for devising multiplication areas
F-RU7a	Depending on crop rotation schemes	M-RU7a †	Each year propagation according to predicted demand	F-A8 High resource dependence M-A8 High resource dependence
			F-A9 Heterogenous per farm	M-A9 -

Source: Own depiction of second-tier variables adopted from McGinnis and Ostrom (2014), with alternative variables for the governance system. As there are multiple resource systems with resource units and actor groups these variables are preceded by an abbreviation for the respective group. Individual variables not found relevant to the case are tagged with ‘-’. Relevant sources for the included variables were mainly interviews 4, 5, 9, 11, 8, 16, 21, 23, 31, and 33; see list appendix 2 table 1. † marks those variables used in the main text.

Action situations for appropriating varietal diversity

Interactions (AV-I)

Outcomes (AV-O)

AV-11	Varieties being bought / farm-saved with license	AV-O1 †	Sustained farming with appropriate varieties; economic and social viability of farm
AV-12 †	Information provided by federal/ state variety trials	AV-O2 †	Farmers find appropriate variety for their biotic and abiotic circumstances
AV-13 †	Deliberation on future variety performance by farmers	AV-O3	Externalities - agricultural system in terms of soil qualities (N), biodiversity outcomes (affected by pesticide/herbicide use), water quality
AV-15 †	Choice of farm-saving or buying certified seed		
AV-17/18	Networking with farmers and between farmers informs variety choice		
AV-19	Farmers monitor their variety performance individually		
AV-110	Farmers evaluate their variety performance individually		