A FARMING SYSTEMS APPROACH IN PRACTICE
Recent examples

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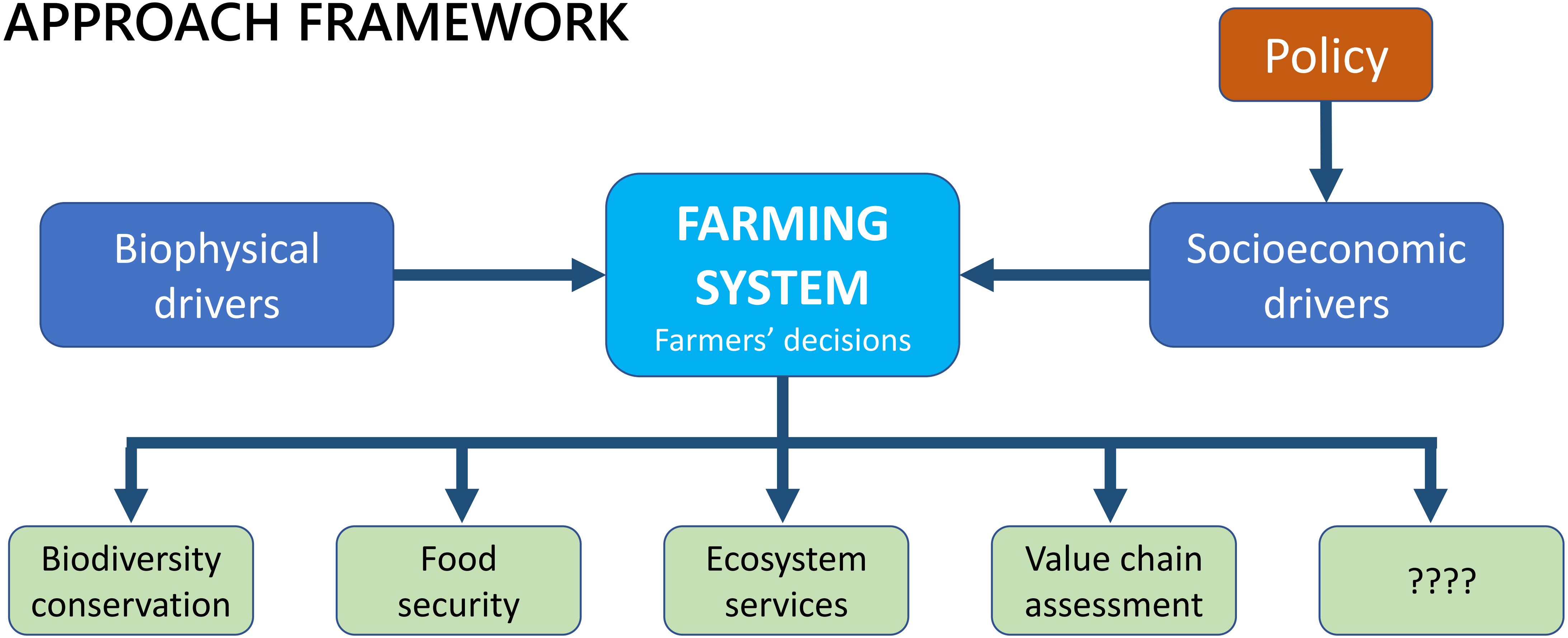
THE FARMING SYSTEMS APPROACH FRAMEWORK



The farming systems approach: some results

Scientific papers in peer reviewed journals

2014 - Modelling **farming system** dynamics in **High Nature Value Farmland** under **policy** change

2016 - An applied **farming systems** approach to infer conservation-relevant **agricultural practices** for agri-environment **policy** design

2016 - Landscape makers and landscape takers: links between **farming systems** and **landscape patterns** along an intensification gradient

2017 - Using beta diversity to inform agricultural **policies** and **conservation actions** on Mediterranean farmland

2018 - A Spatially Explicit Choice Model to Assess the **Impact of Conservation Policy** on High Nature Value **Farming Systems**

2020 - Identifying and explaining the **farming system** composition of **agricultural landscapes**: The role of socioeconomic drivers under strong biophysical gradientes

The farming systems approach: some results (cont.)

Scientific papers in peer reviewed journals

2020 - A **Livelihood** and **Farming System** approach for effective **conservation policies** in Protected Areas of Developing Countries: The case study of the Niassa National Reserve in Mozambique

2021 - Explaining **farming systems** spatial patterns: A farm-level **choice model** based on socioeconomic and biophysical drivers

2021 - A **farming systems** approach to linking agricultural **policies** with **biodiversity** and **ecosystem services**

2023 - **Farming system** change under different **climate scenarios** and its impact on food security: an analytical framework to inform adaptation **policy** in **developing countries**

2023 - Exploring the Effects of **Climate Change** on **Farming System** Choice: A Farm-Level Space-for-Time Approach

2024 - **Farming System** Choice Is Key to Preserving **Surface Water Quality** in Agricultural Watersheds

2024 - A **farming systems** approach to assess synergies and trade-offs among **ecosystem services**

The farming systems approach: some outputs

3 PhD Thesis:

- *Modelling the effects of agricultural policies on high nature value farmland: a **farming systems** approach* (Paulo Flores Ribeiro)
- *A **farming system** approach to support policies for food security under climate change in developing countries: the case of Mozambique* (Máriam Abbas)
- *Exploring the links between **farming systems**, biodiversity and ecosystem services at the landscape scale* (João Ferreira Silva – thesis delivered, awaiting defense)

2 Master Thesis:

- *Modelação da qualidade das águas superficiais ao nível de microbacias com base na ocupação por **sistemas de produção** agrícola* (Fabíola Derossi)
- *Using a citizen-science database and a **farming system** approach to study the functional composition and diversity indicators of breeding birds in Alentejo* (Diogo Almeida – thesis delivered, awaiting defense)

Key steps in applying a FS approach: a recipe

1. Set the scope: **define the problem**; define the area-of-interest; identify potential conflicts / synergies / trade-offs
2. Define the **farming system** (FS) **typology**
   a. Select the analysis units: farm-level? territorial units? (e.g. administrative regions or some artificial grid)
   b. Select relevant (and available) variables for farming system definition (land-use, livestock,…); use only variables that depend on farmers' current management decisions
   c. Apply cluster analysis (apply previous PCA?)
   d. Select the number of clusters (i.e. number of farming systems) to retain (algorithm? expert based?)
   e. Assign the FS to your analysis units: a FS for each farm, or a "FS-Mix" for each territorial unit
   f. Further characterize each FS based on intensity, labour use, specialization, or any other relevant indicators
3. Identify **which FSs** (or FS-Mixes) are of most concern to the ecosystem service or the environmental problem at stake (if this is the case…)

Key steps in applying a FS approach (cont.)

4. What was the **recent trend** of this FS in the study area? If a socially desired FS has a **favorable** trend, then it is likely that nothing needs to be done; but if it is **declining**, then this may trigger a signal for the need for protective **policies**.
5. Select relevant **drivers** of **FS choice**, both biophysical (e.g. climate, slope…) and socioeconomic (e.g. population density, farm size…).
6. Characterize your **units of analysis** (GIS analysis may be needed), building the **database** that will be used in subsequent analyses.
7. Fit the **FS choice model** using statistical approaches (e.g. logistic regression) or machine learning techniques (e.g. random forest ← recommended if the number of FS categories is "high")
8. **Explore relationships** between FS and the predictors (e.g. biodiversity, food security or ES indicators)
9. Use the FS choice model to develop **scenario assessment** e.g. changes in **policy**, climate, market prices, …
10. Discuss results and extract conclusions (**policy recommendations**?)

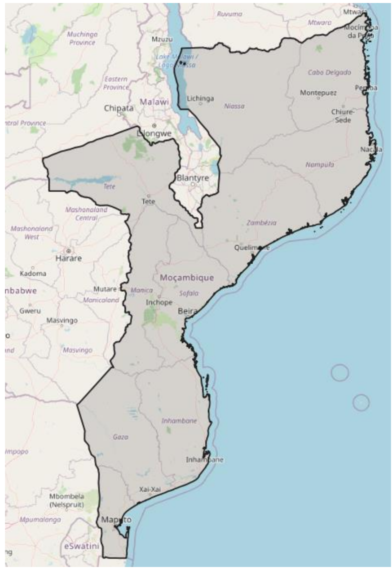
CASE STUDIES

1. MOZAMBIQUE (the whole country)
   Farm-level data, not spatially explicit (Agricultural Census, 2009)

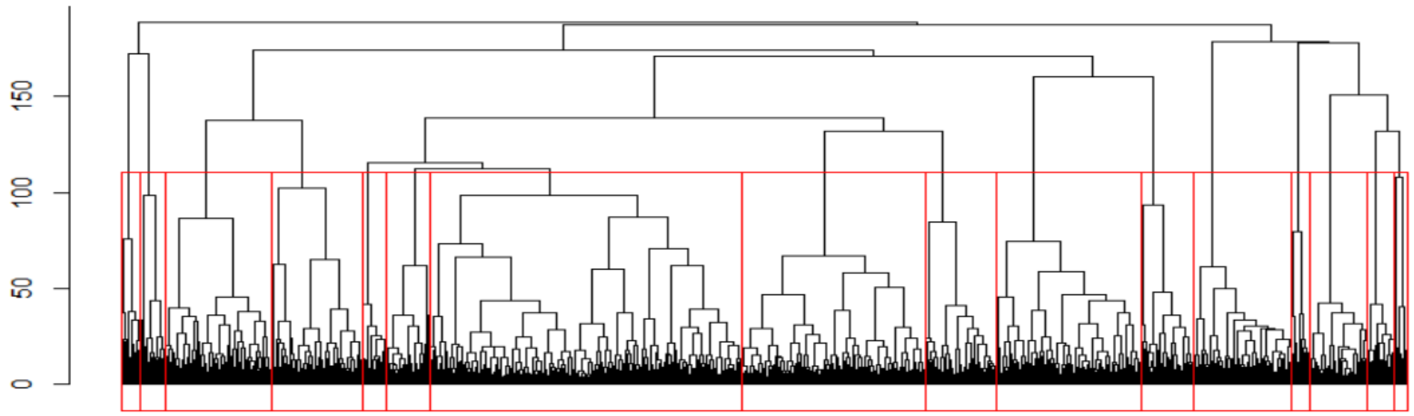
2. CASTRO VERDE (Alentejo, Portugal)
   Farm-level data, spatially explicit, temporal data, from the Portuguese CAP paying agency

MOZAMBIQUE

1. **Climate change → FS choice → Biodiversity / Food security**.
2. **Baseline data**: Agricultural Census 2009 (n=27,805) (plenty of **farm-level** data, but not spatially explicit)
3. 42 variables were used to derive the **FS typology**, describing land use (annual crops), permanent crops (n.º of trees), livestock density and composition (% of each species in total LU), composition of total gross product (% by activity), economic intensity (total revenue / farm area), input use (% of farm area with fertilizers, pesticides…), animal/mechanical traction, labour productivity and intensity, etc.
4. A principal component analysis (**PCA**) was performed on these variables and a hierarchical **cluster** analysis was applied on the most significant PCs, to derive the FS typology



MOZAMBIQUE The cluster analysis output

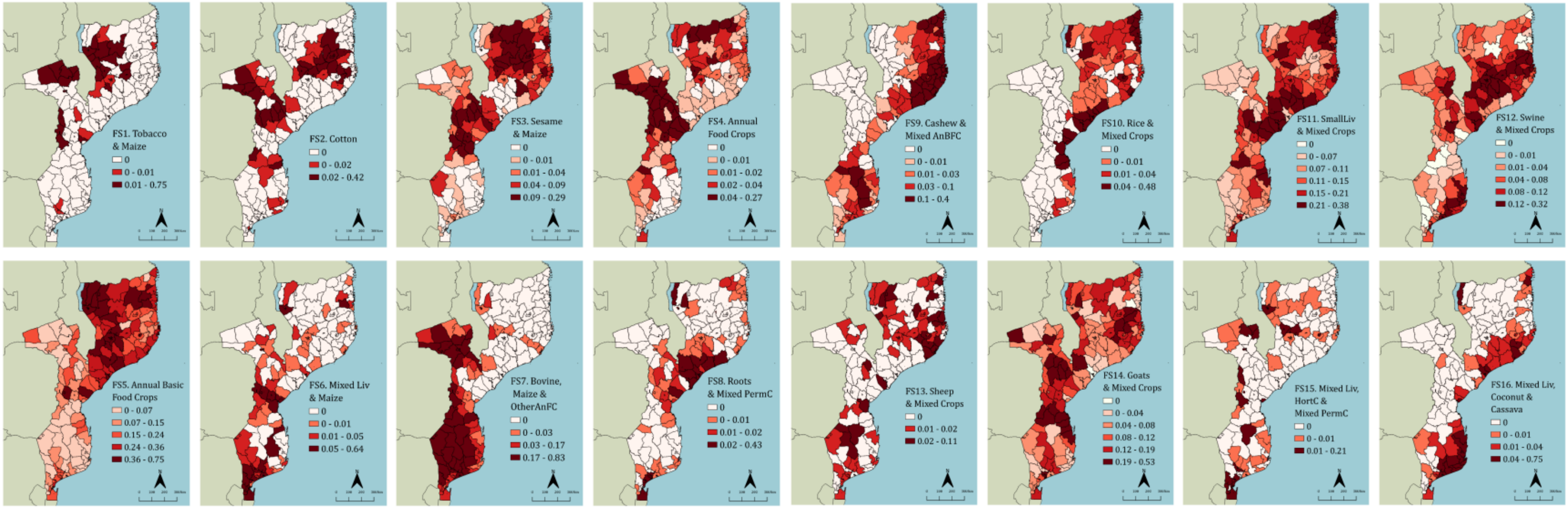


- A solution of 16 clusters (16 FS) was retained →
- Each farm was assigned a cluster (i.e. a FS)
- The "average farm" in each cluster defines and characterizes the farming system

Farming System
FS1 – Tobacco and Maize
FS2 – Cotton
FS3 – Sesame and Maize
FS4 – Annual Food Crops – AnFC (Horticultural Crops, Maize and Sorghum+)
FS5 – Annual Basic Food Crops – AnBFC (Cassava, Maize and Beans)
FS6 – Mixed Livestock and Maize
FS7 – Bovine, Maize and Other AnFC
FS8 – Roots (Cassava and Sweet Potato) and Mixed PermC
FS9 – Cashew and Mixed AnBFC
FS10 – Rice Mixed (PermC and Livestock)
FS11 – Small Livestock (SmallLiv) and Mixed Crops
FS12 – Swine and Mixed Crops
FS13 – Sheep and Mixed Crops
FS14 – Goats and Mixed Crops
FS15 – Mixed Livestock, Horticultural and Mixed PermC
FS16 – Mixed Livestock, Coconut and Cassava

MOZAMBIQUE Farming system mapping

- FS were **mapped** at the District level based on their shares (%) in total agricultural area
- This allowed relating the spatial distribution of FS to a series of spatially explicit biophysical and socioeconomic variables, likely to drive FS choice (including climate!)



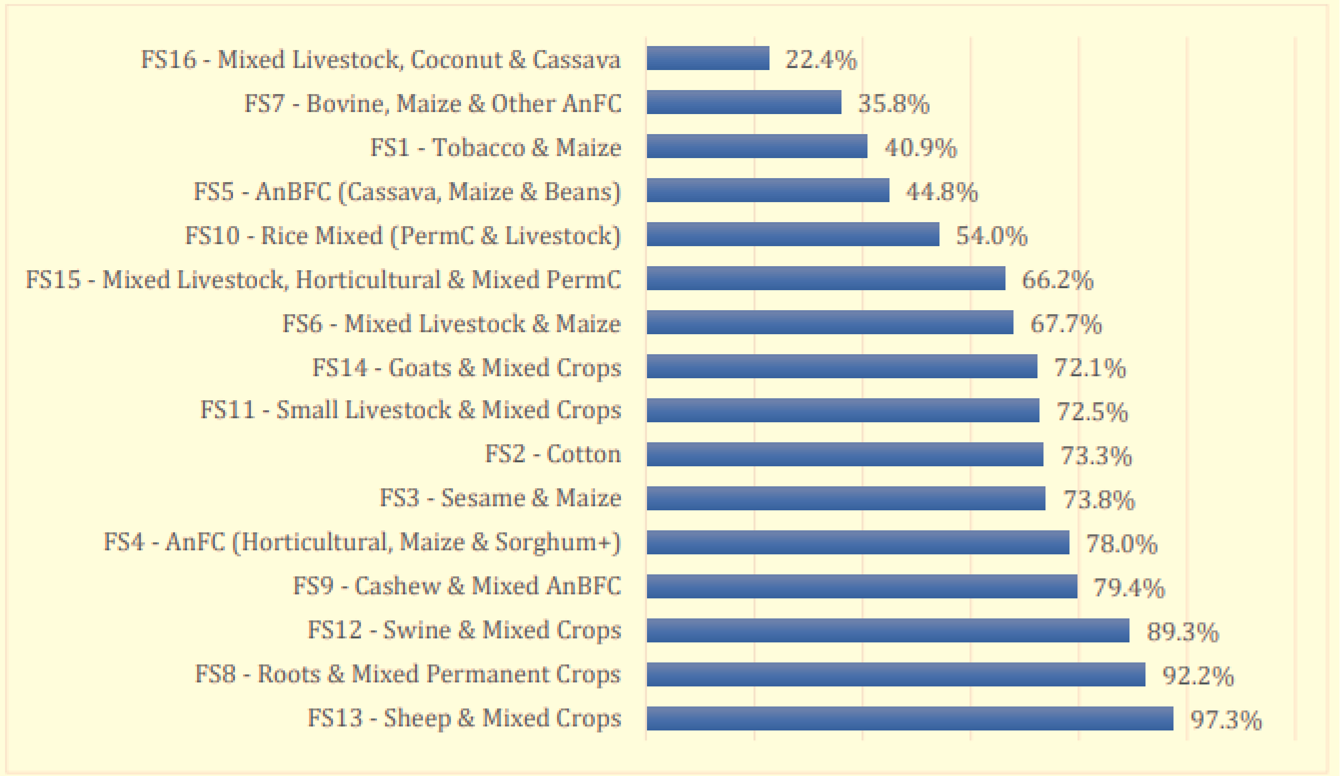
MOZAMBIQUE Drivers of FS choice

- 8 biophysical variables and 7 socioeconomic variables were tested as potential drivers of FS choice
- Farms were characterized based on farm-level data from the Agricultural Census 2009 and based on the average values of the remaining (non-farm-level) variables in the corresponding Administrative Post (the smallest administrative units in MZ)
- A **random forest** model was fit to explore the drivers of FS choice

Variables	Description
Biophysical variables	
MINTEMP	Average minimum temperature in the coldest month 1970-2000 (°C)
AVGTEMP	Average annual temperature 1970-2000 (°C)
RAINFALL	Average annual rainfall 1970-2000 (mm)
ARIDITYINDEX	Aridity Index
SLOPE5	Proportion of administrative post area with smooth slopes (<5%)
SLOPE10	Proportion of administrative post area with steep slopes (>10%)
HIGHFERT	Proportion of administrative post area with high fertility
LOWAREA	Proportion of the farm area in lower, valley bottom locations (1)
Socioeconomic variables	
Administrative post- level	
POPDENS	Population density (inhabitants/km^2)
ROADDENS	Road density (km/km^2)
Farm-level	
HOUSEHOLD	Household size
FARMSIZE	Farm size (ha)
WOMEN	Proportion of farm area managed by women
MARKET	Market integration
PAIDWORK	Proportion of hired labour in total labour units (LU) (2)

MOZAMBIQUE Drivers of FS choice (cont.)

- The prediction accuracy of the **random forest model** is not the same across the FS (average error rate of ≈60%)
- This means that the choice of some FS is highly dependent on these drivers, while other FS are chosen for other (unknown) reasons
- Which drivers are *driving* the choice of each FS?



Classification error estimates

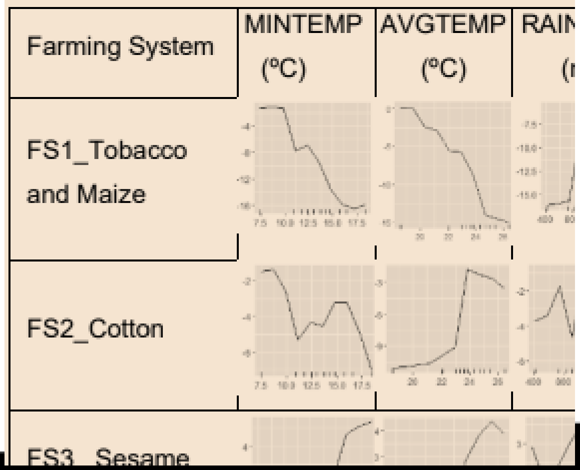
MOZAMBIQUE Drivers of FS choice (cont.)

		MDA Overall Model	FS1 - Tobacco & Maize		FS2 - Cotton		FS3 - Sesame & Maize		FS4 - AnFC		FS5 - AnBFC		FS6 - MixedLiv & Maize		FS7 - Bovine & Maize		FS8 - Roots & Mixed PermC	
BIOPHYSICAL	MINTEMP	73.5	38.9	-	43.4	**	31.5	-/+	27.4	-/+	46.9	+	41.8	-	47.4	-	22.9	**
	AVGTEMP	57.8	24.4	-	31.9	+/-	37.9	+	27.2	+	44.7	-/+	40.4	-	38.0	-/+	22.5	-/+
	RAINFALL	63.7	42.7	+	42.4	**	42.7	+/-	32.5	**	50.6	**	47.6	-	45.1	-	27.8	+
	ARIDITYINDEX	60.4	24.4	+	35.9	**	37.7	-	36.8	-/+	46.4	+/-	31.9	-/+	45.2	-	18.5	+
	SLOPE5	39.8	23.9	-	27.9	**	32.5	**	19.9	-	30.3	**	21.9	-/+	24.3	-/+	17.4	-/+
	SLOPE10	39.1	23.6	+	29.2	**	32.5	**	19.7	+	31.6	**	20.8	-/+	23.5	-/+	15.5	-/+
	HIGHFERT	65.2	17.0	+/-	30.5	-/+	30.2	-/+	19.1	-/+	23.6	-	33.0	+	31.9	+	21.0	+
	LOWAREA	89.7	3.3	-	0.3	**	2.8	-/+	6.6	+	5.2	-/+	9.8	**	14.0	**	6.8	+
SOCIOECONOMIC	ROADDENS	47.0	17.1	-	27.1	-	30.7	-	24.4	-	32.7	+	30.6	+	32.5	+	12.3	+
	POPDENS	57.0	22.7	-	33.0	-	38.2	-	28.4	-	34.2	+	33.5	+	29.5	-	11.4	+
	HOUSEHOLD	62.2	17.1	-	2.2	-	-1.4	-	7.4	-	25.1	-	12.7	+	85.7	+	-0.1	-
	FARMSIZE	88.9	51.7	+	19.0	+	11.1	+	11.2	+	45.0	-	15.1	+	53.2	+	18.8	-
	WOMEN	19.6	12.4	-	12.4	+/-	7.8	-/+	8.4	+	-1.8	-/+	6.5	**	14.8	**	1.7	-/+
	MARKET	143.8	88.4	+	36.8	+	67.9	+	49.1	-/+	61.0	-	2.8	**	30.2	+	8.9	**
	PAIDWORK	58.9	11.7	**	5.6	+/-	-2.1	**	18.3	-	30.7	-	26.2	+	51.7	+	-2.4	**

Variable importance in the random forest model

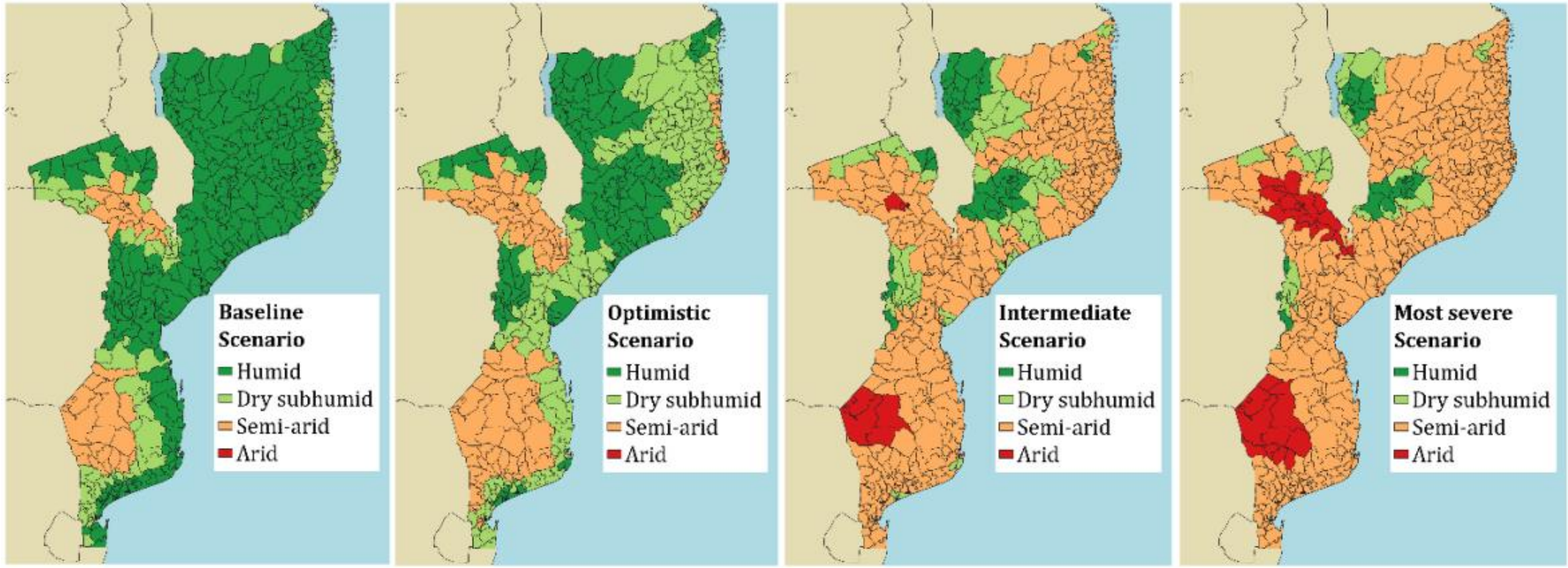
		FS9_Cashew & Mixed AnBFC		FS10_Rice Mixed		FS11_SmallLiv & MixedC		FS12_Swine & MixedC		FS13_Sheep & MixedC		FS14_Goats & MixedC		FS15_MixedLiv, HortC & MixedPermC		FS16_MixedLiv, Coconut & Cassava	
BIOPHYSICAL	MINTEMP	67.8	+	31.5	+	28.7	+	34.9	+	19.2	**	43.6	+	41.7	-	56.6	+/-
	AVGTEMP	36.0	+/-	29.1	+	22.5	+/-	28.4	**	18.0	-/+	33.2	+/-	31.6	-	43.3	+/-
	RAINFALL	44.1	-/+	44.8	+	31.6	+/-	44.6	+/-	21.9	+/-	30.4	+/-	35.0	-	32.6	**
	ARIDITYINDEX	38.3	+/-	32.0	+	25.7	+/-	33.3	+/-	18.8	+/-	26.0	+/-	28.8	-/+	29.7	+/-
	SLOPE5	34.4	-/+	25.6	**	24.5	**	25.0	**	13.9	-	29.6	**	22.4	-	20.0	-/+
	SLOPE10	34.9	+/-	26.7	**	24.2	**	23.6	**	12.2	+	29.3	**	21.9	-/+	20.0	-/+
	HIGHFERT	36.3	-	35.1	+	18.6	-	18.5	-	16.8	-	29.9	-	19.1	**	23.5	+/-
	LOWAREA	4.2	-	97.3	+	19.0	-	9.1	-	9.5	**	10.8	-	55.8	+	58.3	-
SOCIOECONOMIC	ROADDENS	28.7	+	23.7	-	20.9	+	22.5	+	9.5	+	23.6	-	19.0	+	13.0	+
	POPDENS	33.2	+	34.6	-	23.4	+	26.9	+	16.1	-	38.7	+	25.8	+	38.0	+
	HOUSEHOLD	21.8	-	4.6	-	4.7	-	-2.6	-	-2.4	+	10.6	-	4.6	+	13.1	+
	FARMSIZE	8.4	-	34.0	-	8.9	-	7.6	+	-0.8	+	11.4	+	70.5	-	0.9	+
	WOMEN	2.6	-/+	0.2	+/-	16.7	-/+	14.7	**	3.0	**	1.3	**	3.6	-/+	-2.2	-/+
	MARKET	38.2	+	30.6	-	83.4	-	12.5	-	0.5	+/-	45.7	-	6.0	+	11.3	+/-
	PAIDWORK	16.1	-	-3.4	+/-	4.7	-	6.9	-	5.5	+	10.8	-	4.9	+	18.7	**

An example of Partial Dependence Plots



MOZAMBIQUE Impacts of climate change in FS choice

- The (random forest) FS choice model can now be used to explore **scenarios of climate change** and assess its impacts on food security
- A **food security indicator** was built from the Agricultural Census 2009 data, expressing the number of times the household experienced food shortages in the last year
- Climate scenarios were taken from well established climate models (www.worldclim.org)



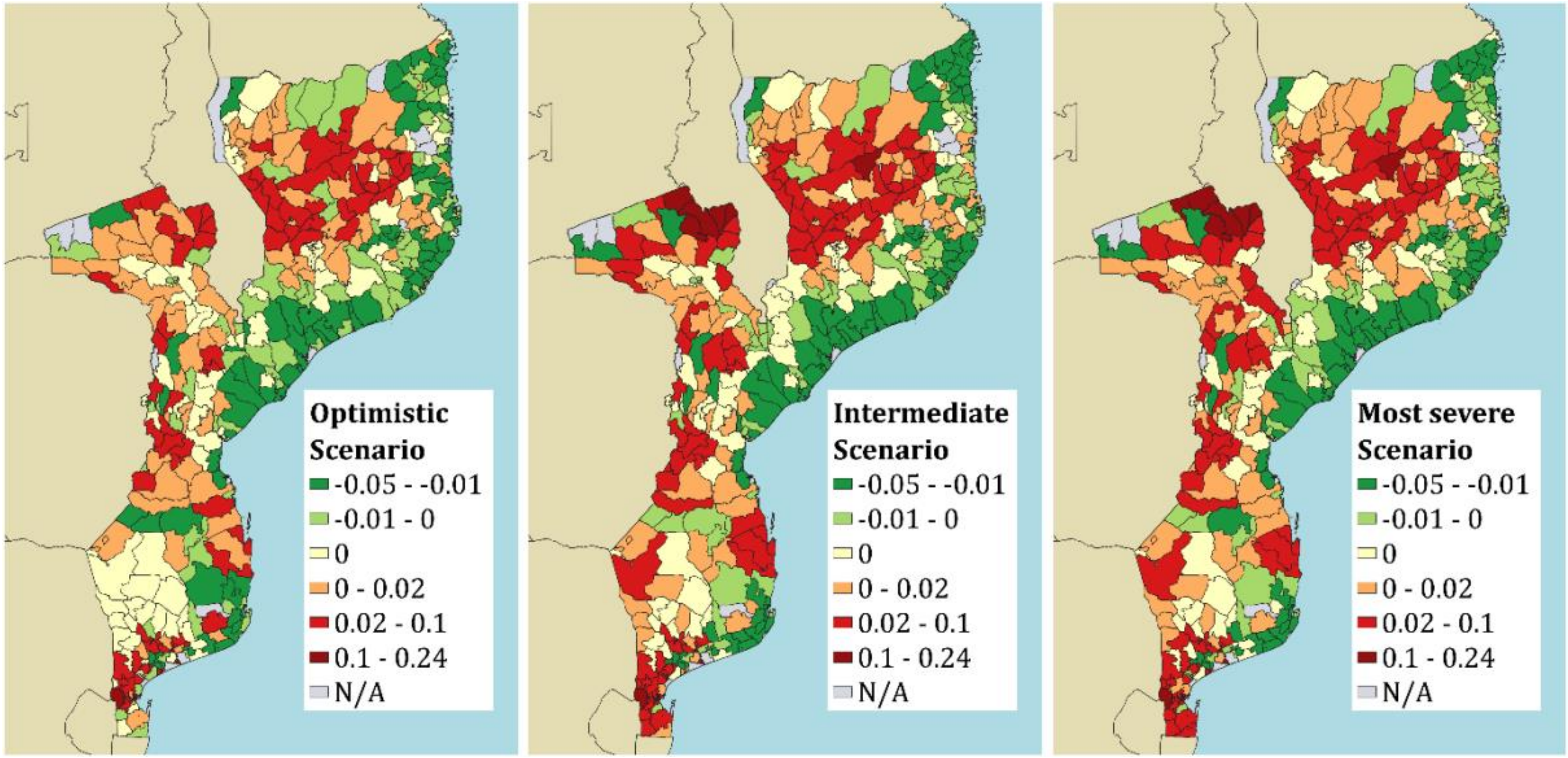
Climate type changes in the long run (2081-2100) in an optimistic, intermediate, and severe scenario

MOZAMBIQUE Impacts of climate change in FS choice

Food security variations as a result of climate change

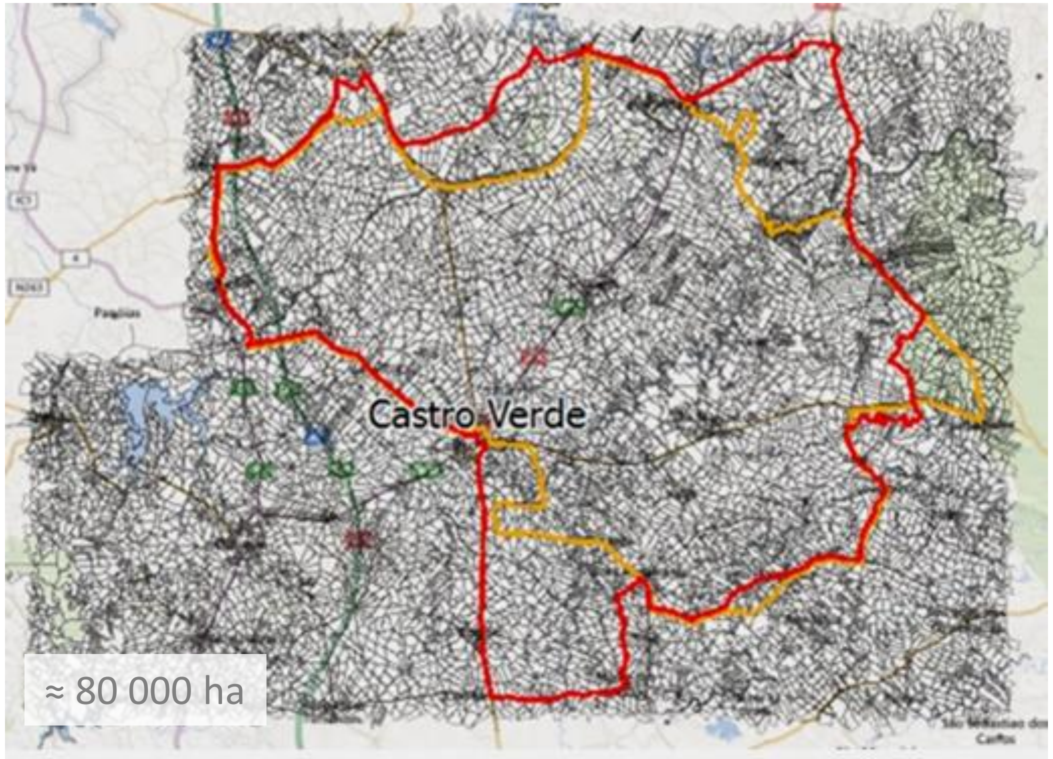
Food security variation was computed as the difference between the percentage of farmers reporting food shortages in the transitioned (final) farming system and the original system

*Critical **priority areas** were therefore identified for public **policy intervention** aimed at helping farmers **adapt to climate change**.*



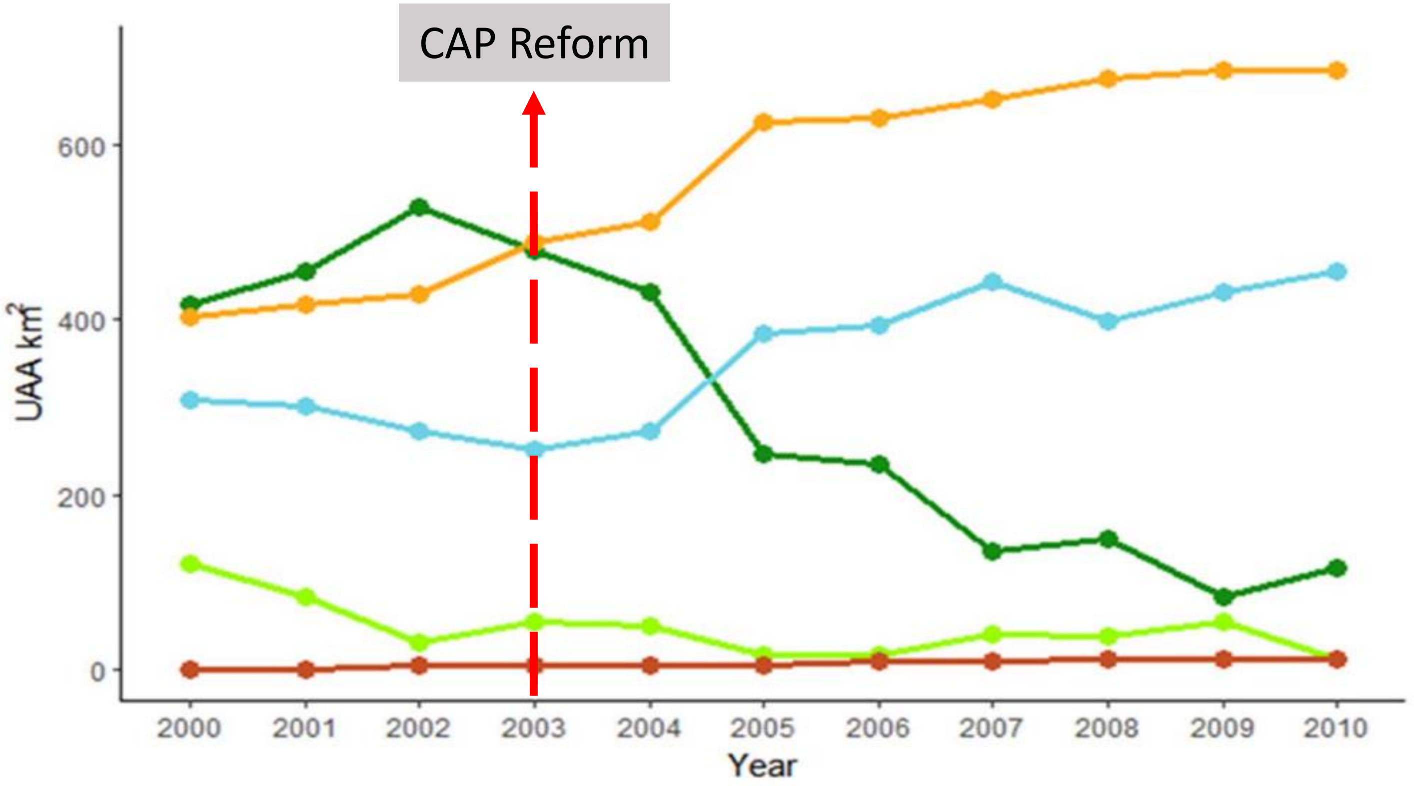
CASTRO VERDE Alentejo, Portugal

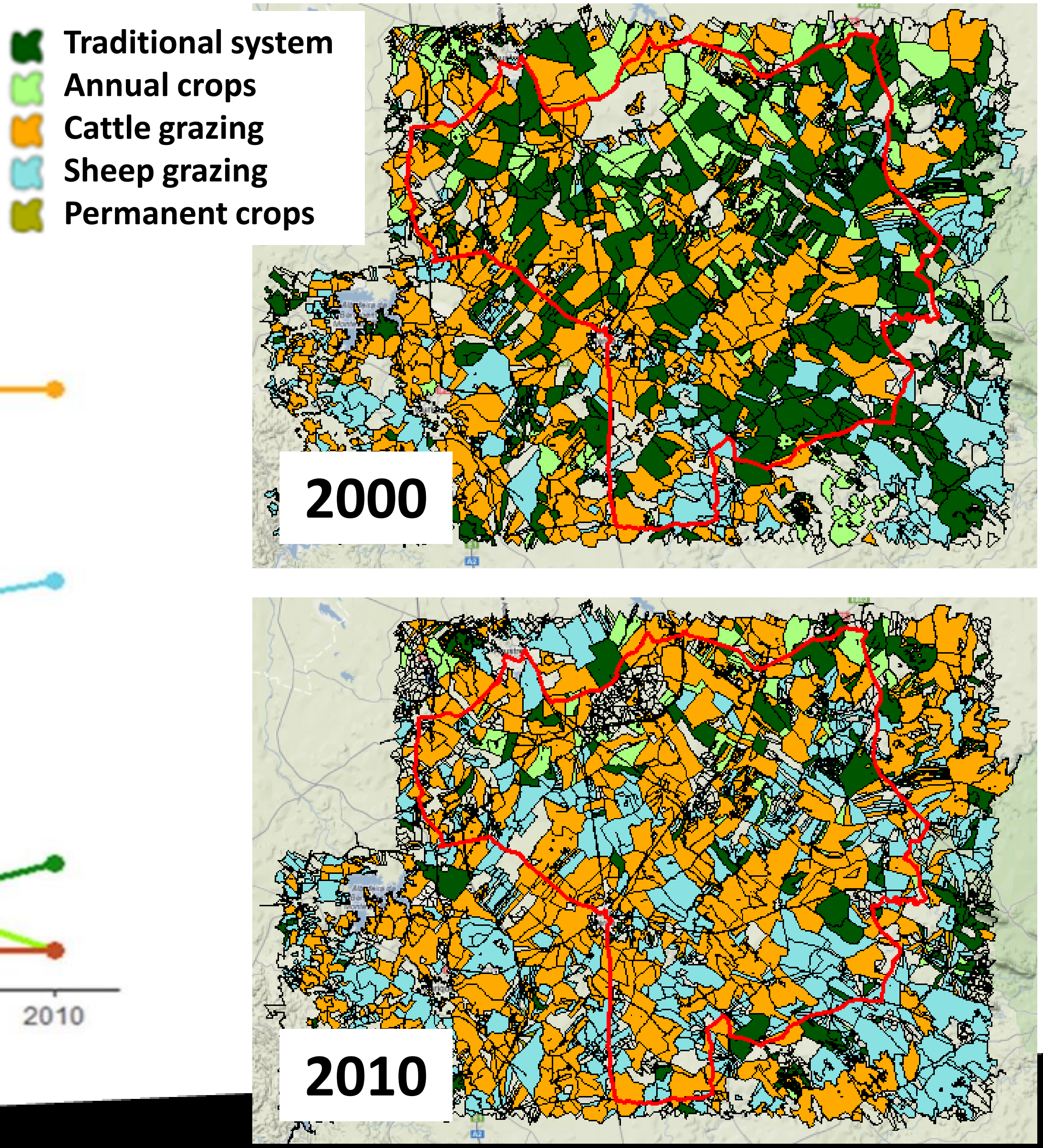
- This is a ***Special Protection Area*** for (steppe) bird conservation, classified under EU legislation ("Birds Directive")
- An **agri-environmental scheme** is in operation in this area since 1995, paying CAP subsidies to farmers that follow a Traditional Farming System
- Spatially explicit farm-level data was available, describing <u>only</u> livestock and land-use pattern, for years 2000 to 2010 (temporal data) → FS typology



CASTRO VERDE Alentejo, Portugal

Farming system dynamics between 2000 and 2010

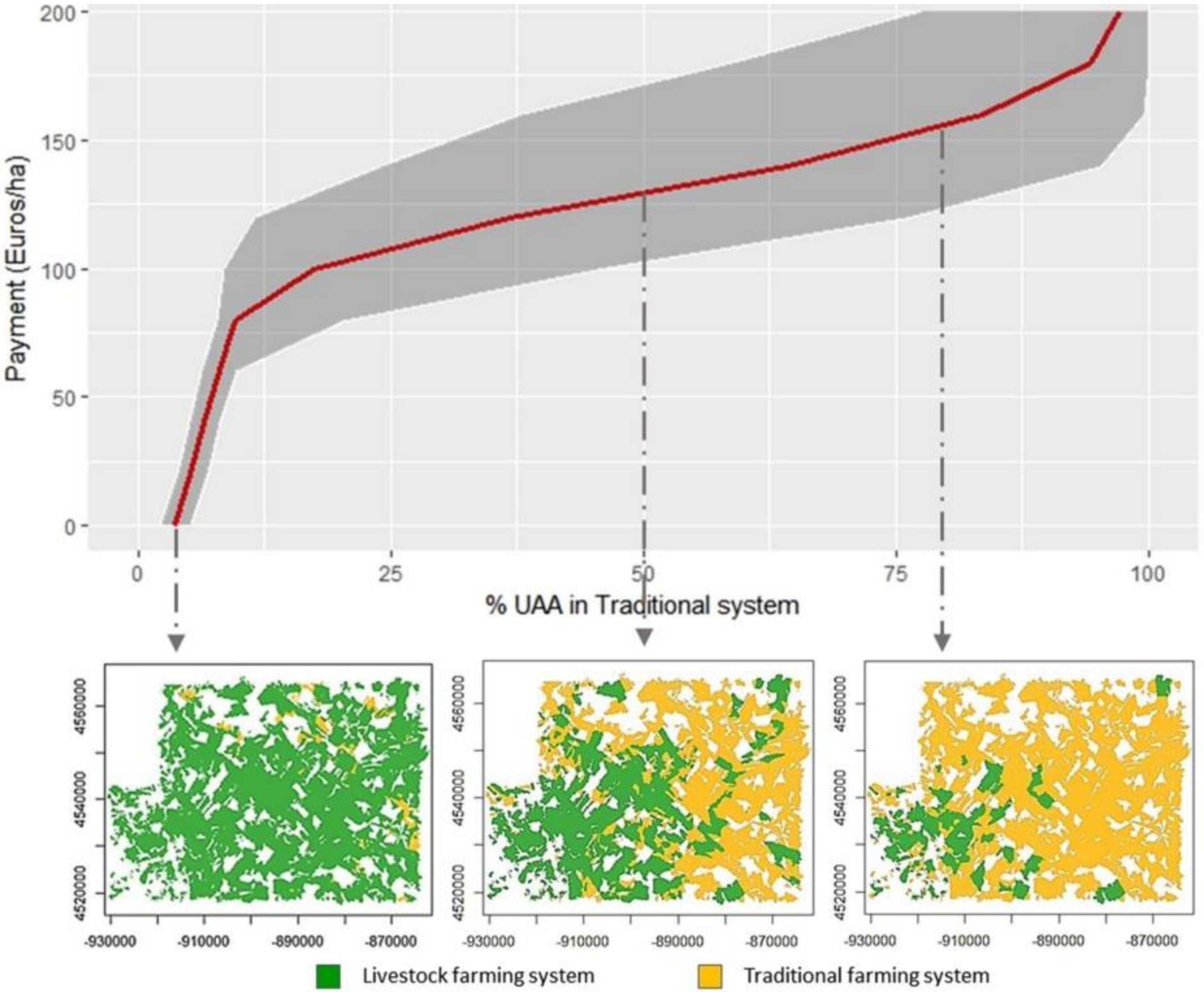




CASTRO VERDE

Modelling FS choice to derive a supply curve for biodiversity conservation services

*Simulating a **policy** paying a premium to farms operating the Traditional System*



Using R as a tool to develop farming systems research

R script example

(available upon request to pfribeiro@isa.ulisboa.pt)

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THANK YOU!