Land use change modelling in CAPRI based on fresh empirical evidence

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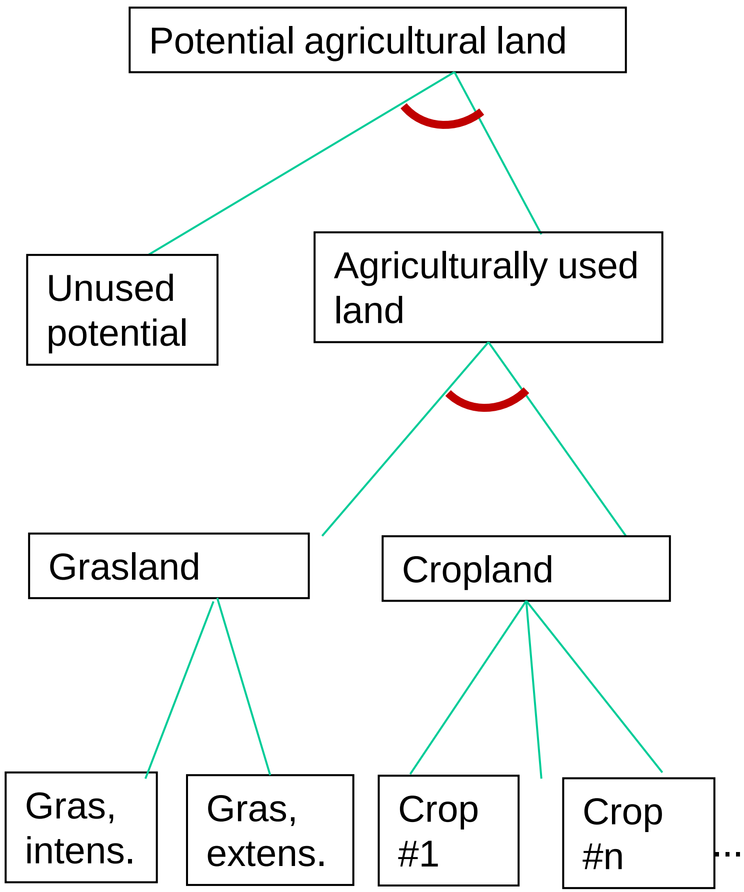
Introduction

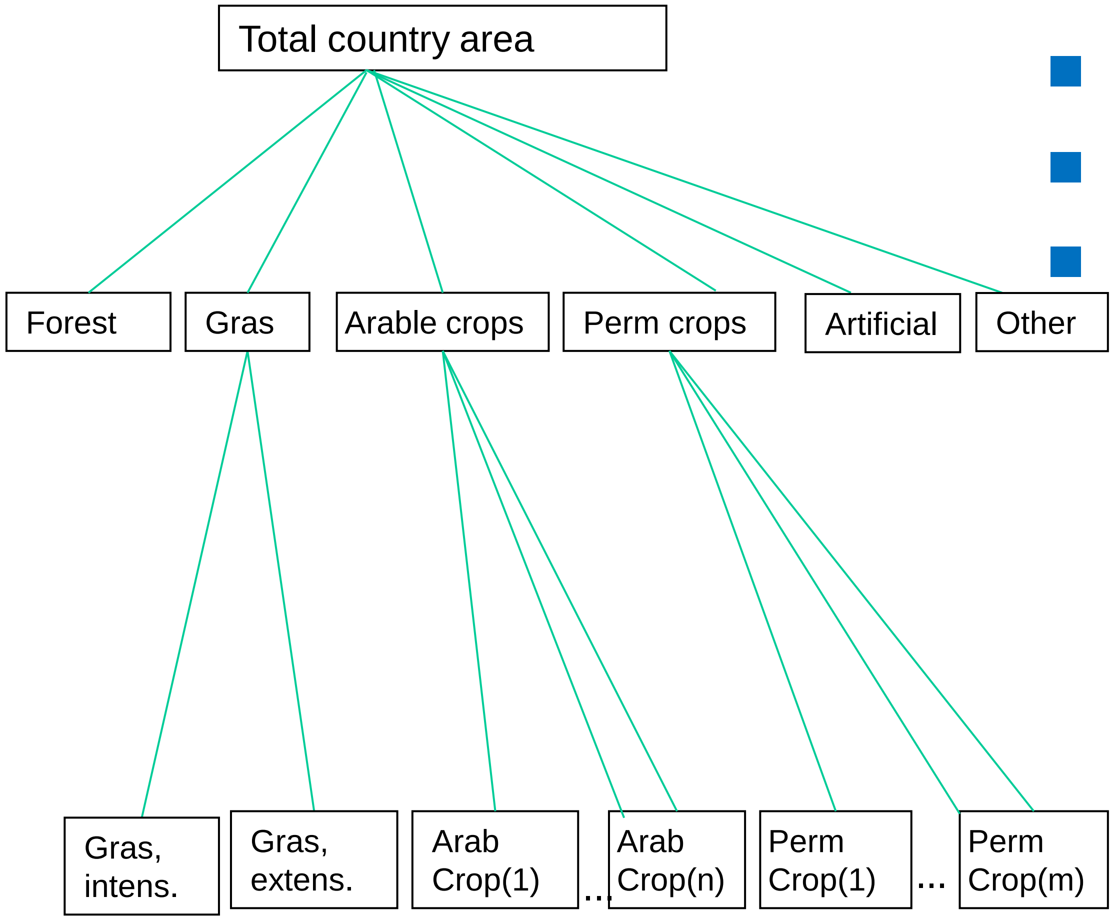
- Key components of CAPRI
  - Regional (NLP) programming models for supply side of European regions
    - ~60 activities, some physical constraints, nonlinear cost => smooth response
  - Global market model (~ 40 regions) iterating with supply models
  - Specific projection tools for baseline
  - Infrastructure for handling outputs of markets, activities, environment
- Land use effects are receiving increased attention
  - For biodiversity questions
  - For carbon accounting. Therefore we need:
    - Full area coverage
    - Land transitions

Land use specification for modelling

- Currently three level hierarchy



- Trustee re-specification



From land owner to land use transitions

Problem:

- CAPRI “levl” classes (of land owner decision makers) do not match perfectly to UNFCCC “land use”
- Some mapping is needed:

Forest	ArableCrops	PermanentCrops	Pasture	InlandWaters	Other	Artificial

LUC matrix „Ireland“ with stable structure

		Forest$_{2008}$	Cropland$_{2008}$	Grasland$_{2008}$	Wetland$_{2008}$	Artificial$_{2008}$	Residual$_{2008}$
		694	633	4179	1084	82	317
Forest$_{2007}$	682	682		0	0	0	0
Cropland$_{2007}$	633	1	627	4		0	
Grasland$_{2007}$	4184	4	5	4174		1	
Wetland$_{2007}$	1091	7		0	1084		
Artificial$_{2007}$	81					81	
Residual$_{2007}$	317	0				0	317

Static land owner problem

- Problem: allocate total land to types *i* receiving specific rents r_i
- The technology for preparing or maintaining the capacity of land is unknown
- We approximate the unknown cost function with a quadratic function

$$\min \sum_i LEVL_i r_i - \sum_i LEVL_i c_i - \tfrac{1}{2} \sum_{ij} LEVL_i D_{ij} LEVL_j$$

$$s.t.$$

$$\sum_i LEVL_i = \text{constant}$$

- An infinite number of (gross) land transitions is possible to move from one allocation of land types to the next one
- No explicit (dynamic) conversion costs => the choice of particular land transitions (among the infinity of feasible ones) will be considered a stochastic process

Dynamic land use change process

- Total land use of each type *i* are given by the economic model
- We must convert economic land $LEVL_i$ to GHG-accounting land LU_k
- Historical data on *gross transitions* T_{jk} show a rather stable pattern
- We use historical transition matrix as (Bayesian) *prior distribution*
- We choose the transition matrix that maximizes density and satisfies land use
- Gamma prior density (*p*) gives good results (only positive outcomes allowed)

$$\max \prod_{jk} p_{jk}\left(T_{jk}\right)$$

$$s.t.$$

$$LU_k = \sum_i share_{ki} LEVL_i$$

$$LU_k = \sum_j T_{jk}$$

$$LU_j^{initial} = \sum_k T_{jk}$$

Parameter estimation based in historical data and WP2.3 results

- Elasticities of WP2.3 aggregated to CAPRI-regions (to Nuts2 from grid)
- Problem: Specify land supply model to minimize deviations from WP2.3 results
- Convex quadratic, linearly constrained model…
  1. Can fit observed land use and land rents exactly
  2. Can get “close” to a point elasticity matrix (as constraints and curvature permit)
- “Close” is measured by weighted square deviations
  - Diagonal has higher weight
  - Off-diagonal has lower weight
  - Residual elements have lowest weight
- (Transitions calibrated by setting “prior mode” = “observation”)

Results on prior and posterior elasticities

To get "priors" for CAPRI (below), elasticities estimated by Jean Saveur Ay were

1) Squeezed into a [0,1] range by a cut off rule plus shrinking formula
2) Aggregated without weighting from km2 results to NUTS3 level and then NUTS2
3) Ignoring the warning against use of elasticities for urban land
4) And recalculating the (numeraire) *Other* land elasticity based on assumptions

		Pasture	Forest	Artificial	Other	ArabCrops	PermCrops
prior	Pasture	**0.09**	-0.13	-0.15	0.27	-0.08	-0.01
prior	Forest	-0.02	**0.14**	-0.23	0.19	-0.07	-0.01
prior	Artificial	0.03	-0.14	**0.88**	-0.82	0.05	-0.01
prior	Other	-0.02	0.03	0.12	**-0.16**	0.04	-0.01
prior	ArabCrops	0.01	-0.17	-0.17	-0.39	**0.55**	-0.01
prior	PermCrops	0.03	-0.01	-0.07	0.11	-0.07	**0.05**
fitted	Pasture	**0.06**	-0.01	0.00	-0.05	0.00	0.00
fitted	Forest	-0.03	**0.13**	-0.03	0.03	-0.10	0.00
fitted	Artificial	0.03	-0.16	**0.88**	-0.21	0.04	0.00
fitted	Other	-0.07	0.01	-0.01	**0.12**	-0.04	0.00
fitted	ArabCrops	0.01	-0.23	0.02	-0.34	**0.47**	0.00
fitted	PermCrops	0.03	-0.01	-0.08	0.08	-0.07	**0.05**

Example: IR01 = Border, Midland, Western

1) Strong changes for other land elasticity where variance has been set high
2) Other elasticities are closer top prior

Scenario with +200 Euro support for pasture and meadows

- In IR01 (Border, Midlands, Western) land owners would expand pastures (agricultural grassland), mostly at the expense of “other land”.
  - As arable and permanent crops had low cross elasticity to pasture rents
- Effect on UNFCCC grassland is moderated as a part of pasture expansion comes from the “shrubland” (so takes place within grassland)
- Expansion partly at the expense of wetland (part of other land) problematic?

	Levl	LU	Reference	Simulation	Change (%)	Change (kha)
Forest	X	X	328	325	-0,9%	-3
Artificial	X	X	24	24	0,9%	0
Cropland		X	165	165	0,2%	0
ArableCrops	X		164	165	0,2%	0
PermanentCrops	X		0	0	0,0%	0
Pasture	**X**		**1561**	**1590**	**1,8%**	**29**
InlandWaters	X		116	116	0,0%	0
Other	**X**		**1119**	**1093**	**-2,3%**	**-26**
Wetland		X	672	660	-1,9%	-13
Grassland		X	1929	1949	1,0%	20
Residual		X	195	190	-2,3%	-5

Unfinished business

- Full implementation in CAPRI
  - Adjustments to new parameters, variables in calibration, simulation, post model reporting
- Reconsidering / fine tuning details of estimation approach
  - Distributions for elasticity information (Gamma for diagonal?)
  - Use of variance information from multinomial logit estimation in CAPRI
  - Introduction of prior information at grid level vs NUTS2 level
  - Constraint for second order condition
  - Handling of missing / suspicious data
- Completion for countries not covered (Scandinavia, NMS...) or search for plausible mapping rules
- Adjustment of elasticities to baseline changes in land allocation
  - Special elasticities have been provided, more info on regressors might be obtained

Outlook for longer run

- Carbon accounting to be moved from post model to during model
- Permits GHG mitigation scenarios integrating
  - Mitigation measures targeting non-CO2 emissions from livestock production and crop production
  - Carbon effects in LULUCF sector
- For global climate effects (ILUC)
  - Completion on global database on land transitions
  - Modelling of transitions may rely on same concept (unknown statistical dynamic process) as in EU programming models
  - Permits scenarios with global carbon price policies and mitigation in several world regions