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Optimal scales of neighbourhood effects on land-use change: An analysis procedure applied in an Alpine mountainous region

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Abstract: Neighbourhood effects on land use change are very common. Therefore, they are often included in spatially explicit models of land use change and other spatial analyses. Neighbourhood indices, however, depend strongly on the spatial extent set for calculating them. So far, most of the existing land-use change analyses or models using neighbourhood indices assumed some predefined neighbourhood extents without proving whether the selected extents are optimal for the analysis of the corresponding land use dynamics. This paper presents a methodological procedure to identify (i) the optimal neighbourhood extent and (ii) the range of scale-dependency in neighbourhood effects of different land use types and different types of land conversions. We applied this procedure in the canton Valais of Switzerland, an inner Alpine mountainous region. The findings clearly show the differences in optimal neighbourhood extent and the scale-dependency among conversion types. The procedure introduced in this contribution can help to optimize the neighbourhood variables in spatially explicit land-use change models toward improving model robustness and accuracy.

Keywords*: Neighbourhood effect; land-use change; modelling; land-use dynamics; scale-dependency*.

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Optimal scales of neighbourhood effects on land-use change: An analysis procedure applied in an Alpine mountainous region

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Agenda

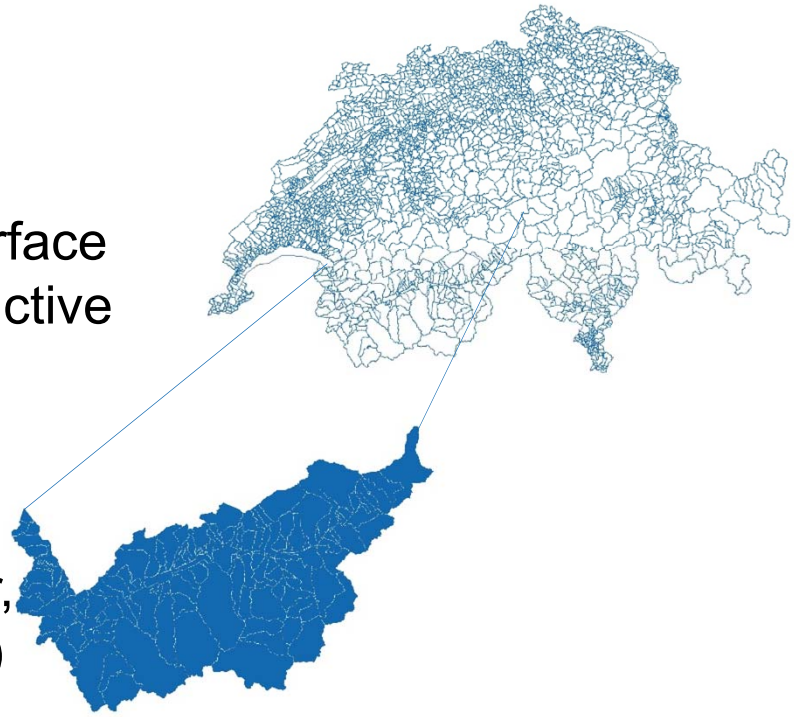
- Introduction -> Neighborhood effects in LUCC modeling
- Data & Methods
  - Case study region
  - A practical procedure to identify optimal neighborhood extents and the range of scale-dependency
  - Hypothesis
  - Data -> land-use transitions in case study region
- Results
  - Pattern of neighborhood effects
  - Neighborhood effect and conversion type
  - Range of significant neighborhood effect and conversion type
- Conclusion

Introduction

- Neighborhood effects on land use change are common, therefore they are often included in spatially explicit models of land use change.
- Common assumption held by many LUCC models: Neighborhood effects are not specific to spatial extents, type of land use and land use conversion.
- This paper presents a methodological procedure method to identify
  - (i) the optimal neighborhood extent, and
  - (ii) the range of scale-dependency in neighborhood effects of different land use types on different land conversions

Study area

- Canton of Valais, Switzerland
- Dry inner-alpine mountain region
- 5225 km²: Forest (24%), Agricultural surface (19%), Settlement area (3.5%) Unproductive area (53.5%)
- 300’000 inhabitants
- Important tourist destination, north-south traffic and transport corridor, industry sector (hydropower, chemicals)



Method

- Characterization of land-use neighborhood characteristics:

$$E_{i,k,r} = \left(\frac{n_{i,k,r}}{n_{k,r}}\right) / \left(\frac{N_k}{N}\right)$$

$E_{i,k,r}$ = enrichment factor of land use ***k*** within neighborhood ***r*** of the considered pixel ***i***
$n_{i,k,r}$ = no. of pixels with land use ***k*** within neighborhood ***r*** of the considered pixel ***i***
$n_{k,r}$ = no. of all pixels within neighborhood ***r*** of the considered pixel ***i***
Nk = no. of pixels with land use ***k*** in the study area
N = total no. of pixels in the study area

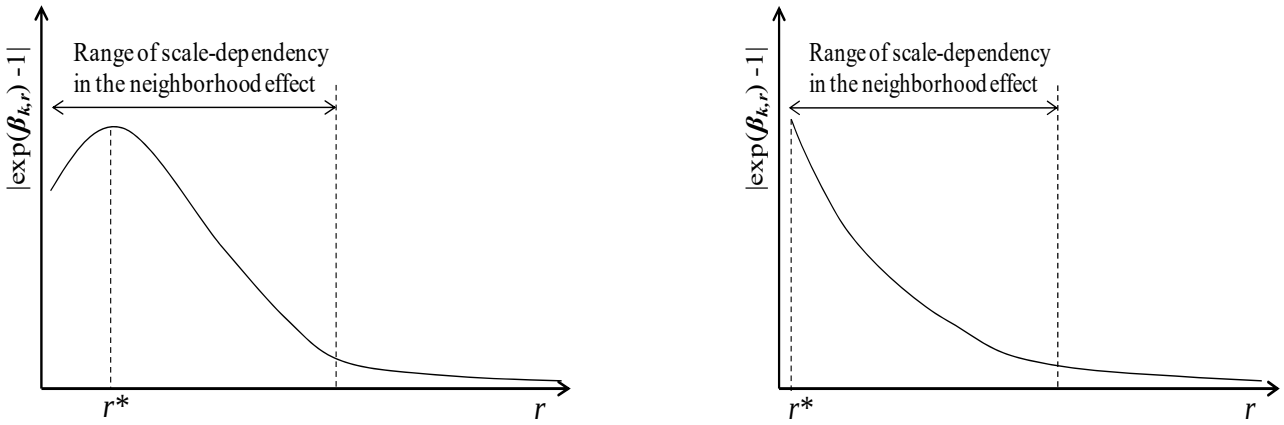
- Identification of optimal scales of neighborhood effects on land use change: Binary logistic regression:

$$ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_{k,r} E_{i,k,r}$$

P_i= probability of a conversion considered at pixel ***i***
$ß_{k,r}$ = weight of the effect of land use k within neighborhood ***r*** **(**of the considered pixel ***i***)

Hypothesis

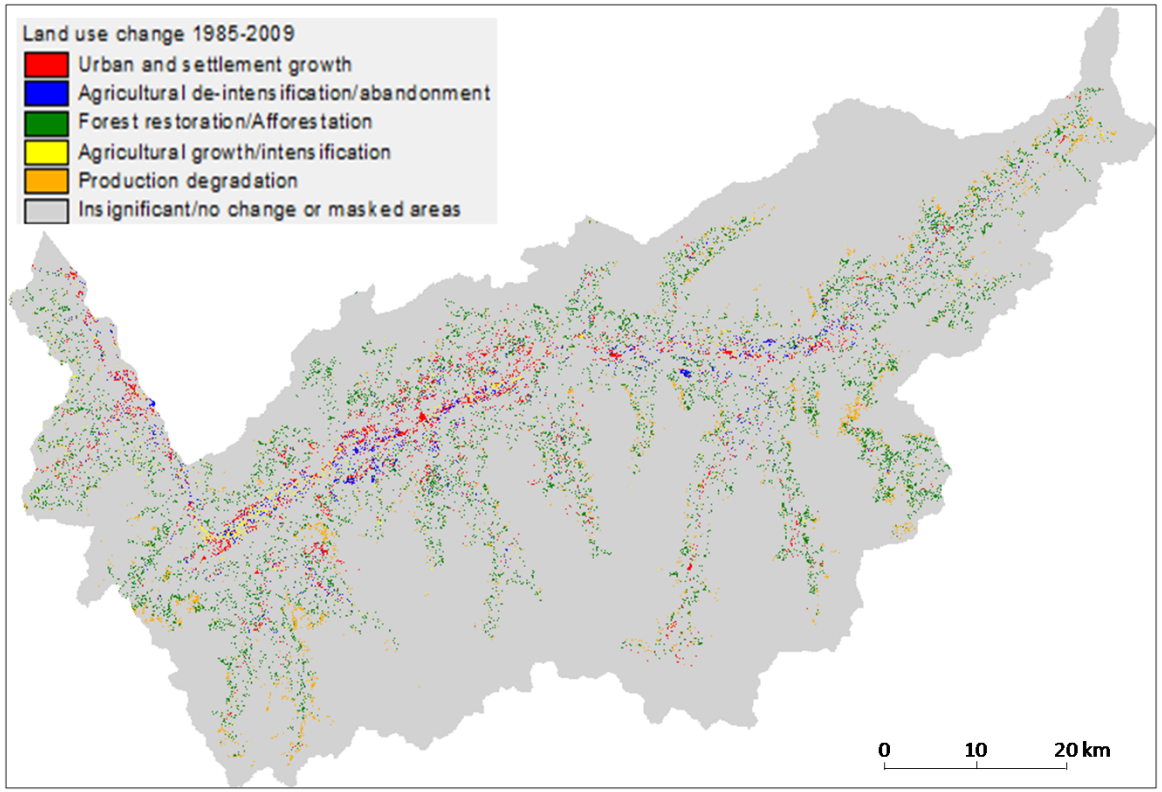
- Scale-specific effects of neighborhood land uses on LUCC:



- The optimal neighborhood extent (r*), the range of scale-dependency in the neighborhood effects and the curve behavior (i.e., if type (a) or (b) occurs) are hypothesized as variable over different neighborhood land use factors and conversion types.

Data

- Spatial pattern of historical land-use conversions



Data

- Land-use transformation matrix based on areal statistics

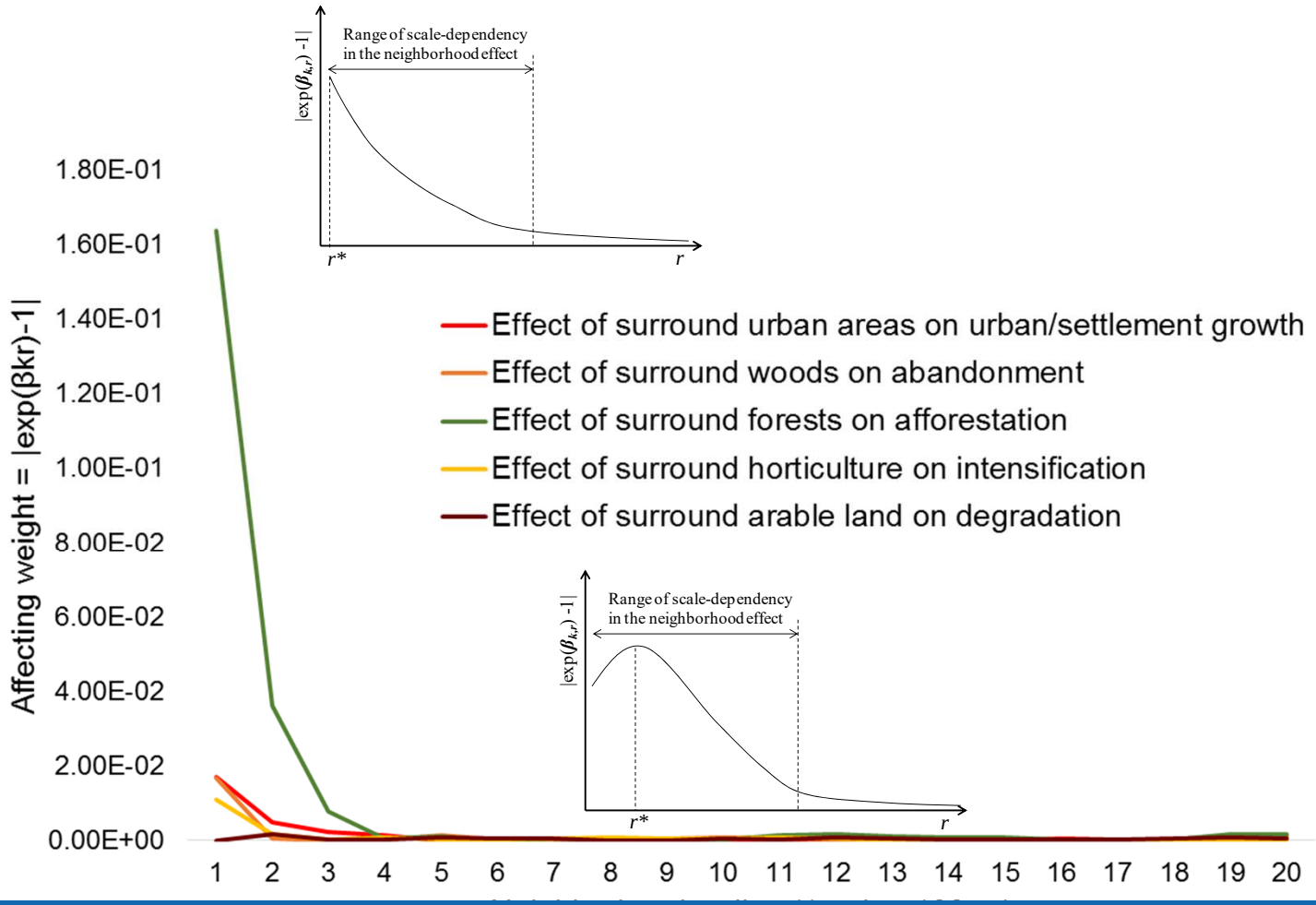
1985	2009 Urban and settlement areas	Orchard/ vineyard/ horticulture	Arable land	Meadows/ farm pastures	Alpine meadows/ pastures	Forests	Woods	Unprod. vegetation	*Total area (ha) in 1985*
Urban and settlement areas	13760 (97)	34 (0)	21 (0)	109 (1)	39 (0)	109 (1)	23 (0)	65 (0)	*14160* *(100)*
Orchard/vineyard/ horticulture	1041 (11)	7699 (78)	565 (6)	437 (4)	0 (0)	24 (0)	38 (0)	18 (0)	*9822* *(100)*
Arable land	798 (15)	579 (11)	3708 (70)	213 (4)	0 (0)	2 (0)	18 (0)	9 (0)	*5327* *(100)*
Meadows/farm pastures	2030 (10)	188 (0)	116 (0)	16249 (78)	13 (0)	841 (4)	1240 (6)	202 (1)	*20879* *(100)*
Alpine meadows/pastures	529 (1)	1 (0)	0 (0)	201 (0)	67150 (90)	1828 (2)	1257 (2)	3658 (5)	*74624* *(100)*
Forests	360 (0)	33 (0)	21 (0)	208 (0)	176 (0)	100352 (98)	360 (0)	637 (1)	*102147* *(100)*
Woods	334 (2)	54 (0)	14 (0)	615 (4)	202 (1)	3990 (29)	8270 (60)	264 (2)	*13743* *(100)*
Unproductive vegetation	174 (0)	44 (0)	6 (0)	52 (0)	118 (0)	4705 (8)	1530 (2)	56085 (89)	*62714* *(100)*
Total area (ha) in 2009 (2)	*19026*	*8632*	*4451*	*18084*	*67698*	*111851*	*12736*	*60938*	
Net change ((2)-(1)) (ha)	*+4866* *(+34)*	*-1190* *(-12)*	*-876* *(-16)*	*-2795* *(-13)*	*-6926* *(-9)*	*9704* *(10)*	*-1007* *(-7)*	*-1776* *(-3)*	

Meanings of the cell's colors

- No change
- Urban/residential growth
- Agricultural de-intensification/abandonment
- Forest restoration/afforestation
- Agricultural growth/intensification
- Production degradation

White cells: no/insignificant change, i.e., the changed area < 100 ha and < 1% of the initial area of the corresponding land use type.

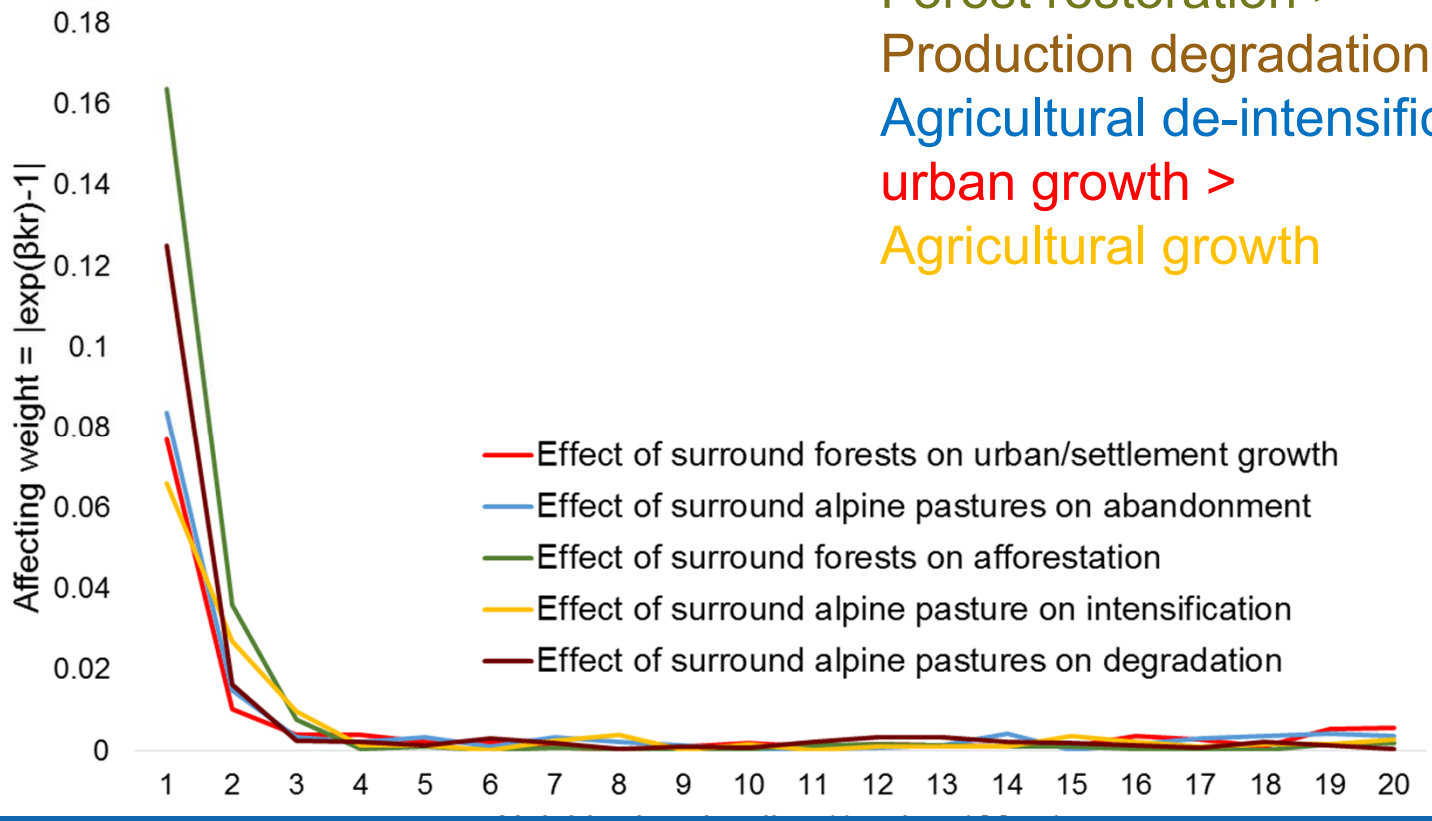
Results: Pattern of neighborhood effects



➢ Mountain specific pattern > Different from other studies in Europe (e.g. The Netherlands in Verburg et al.)

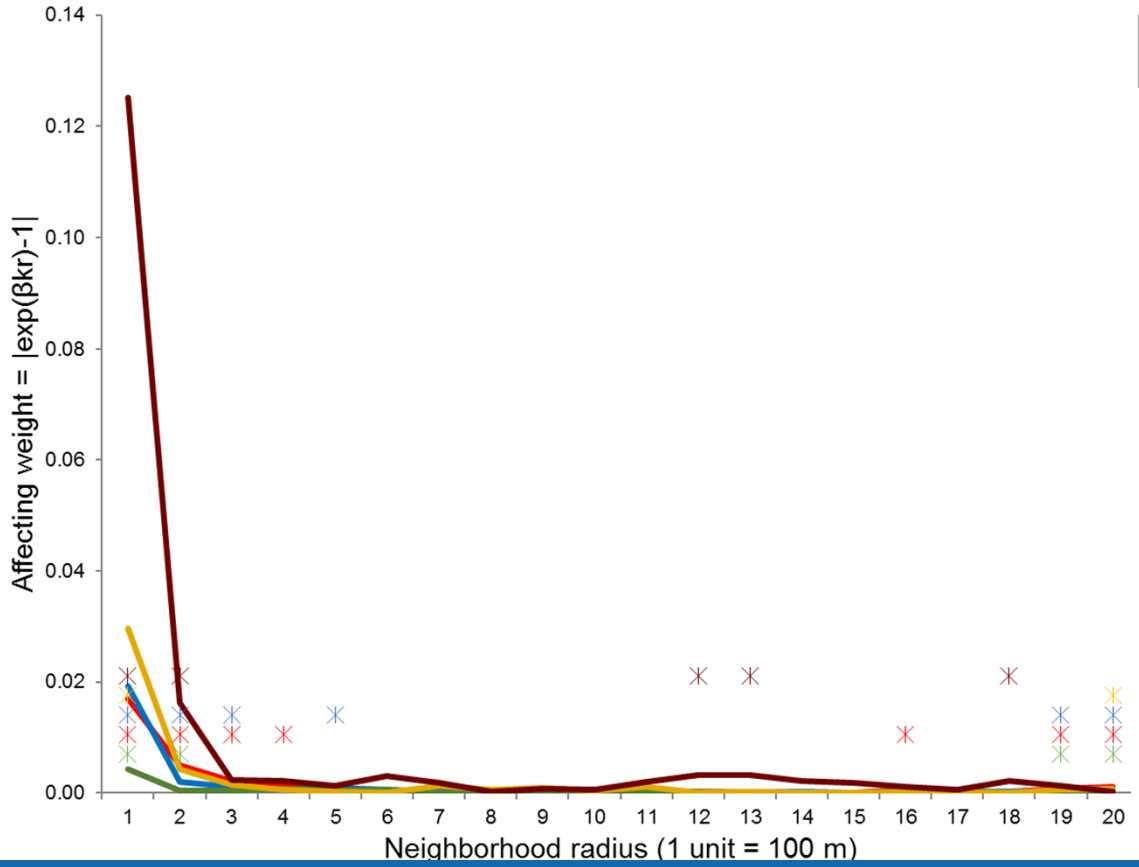
Results: Importance of neighborhood nature effect vs. conversion type

Forest restoration >
Production degradation >
Agricultural de-intensification or
urban growth >
Agricultural growth



➢ Neighborhood variables in LUCC model should be specific to conversion type

Results: Range of significant neighborhood effect vs. conversion type



Strong effects (with high magnitude and significance) take place within a zone of 200 – 500 m diameter

AND

Significant effects place at the distance > 1.6 km. The affecting magnitudes are small, but may be important in LUCC model with strong path-dependency like Cellular Automata or ABM.

➢ For a given conversion, consideration of multiple neighborhood variables (with different extents) would be necessary.

Conclusions

- Implications for modeling
  - Neighborhood variables need to be specific to conversion type.
  - Consideration of multiple neighborhood variables would be necessary.

- Implications for regional management
  - Upkeep of Alpine pastures strongly influence land degradation and afforestation -> Spatial explicit policy measures needed to maintain scenic landscapes for tourism.
  - Spatially explicit identification of Hot-Spots will allow to control for unwanted land-use changes (i.e., urban growth on productive agricultural area in the bottom of the valley) -> Landscape planning.