Heft 118

Hydrological Consequences of Land Use / Land Cover and Climatic Changes in Mesoscale Catchments

von

Dr.-Ing. Luis E. Samaniego E.

Technische Hochschule Darmstadt
Institut für Wasserbau und Wasserwirtschaft
Fachgebiet Wasserbau
HP VI 30. OKT. 2003
Inv. Nr. R 18323

Eigenverlag des Instituts für Wasserbau an der Universität Stuttgart

Table of Contents

List of Figures v
List of Tables ix
List of Symbols xi
Acronyms and Abbreviations xix
Acknowledgement xxi
Zusammenfassung xxii

Chapter 1
Introduction 1

1.1 Description of the problem ... 1
1.2 The complexity of modelling the water system at the mesoscale level ... 5
1.3 Empirical quantifications ... 8
1.4 Research question and objectives ... 9

Chapter 2
Foundations of the Study 10

2.1 Introduction ... 10
2.2 General description of the Study Area ... 11
2.3 Conceptualisation of the runoff process at the mesoscale level ... 13
2.4 Spatial units ... 15
2.5 Physiographical factors ... 16
2.5.1 Basin's area [km²] ... 17
2.5.2 Mean slope [°] ... 17
2.5.3 Median of the slope [°] ... 18
2.5.4 Trimmed mean of the slope [°] ... 19
2.5.5 Mean stream slope [°] ... 19
2.5.6 Mean slope of the areas located at the floodplains and riparian land of the stream network [°] ... 20
2.5.7 Drainage density [1/km] ... 21
2.5.8 Shape factor [-] ... 22
2.5.9 Fraction of north- and south facing slopes [-] ... 22
2.5.10 Mean basin elevation and difference between maximum and minimum altitudes [m] ... 23
2.5.11 Fraction of saturated areas [-] ... 24

2.5.12 Mean field capacity [mm] 26
2.5.13 Fraction of karstic formations [-] 26
2.6 Land-use and land-cover 27
2.6.1 The land cover time series 30
2.6.2 Fraction of a given land cover [%] 32
2.7 Climatic or meteorological factors 33
2.7.1 Precipitation 33
2.7.2 Temperature 40
2.7.3 Circulation Patterns [-] 43
2.8 The system's output: runoff 46
2.8.1 Specific runoff [mm] 47
2.8.2 Characteristics of high flows 48
2.8.3 Characteristics of low flows 51

Chapter 3
Parametric modelling of the runoff process **54**

3.1 Basic principles 54
3.2 Defining the formal system 55
3.3 Modelling the long-term mean of the annual specific discharge 57
3.3.1 Introduction 57
3.3.2 Modified forward selection 60
3.3.3 Modified backward elimination 61
3.3.4 Building all combinations 62
3.3.5 Selection of the best models using Mallows' C_{p*} statistic 63
3.3.6 Model validation 64
3.3.7 Significance test 65
3.3.8 Analysis of results 69

Chapter 4
Modelling characteristics of the runoff process with time-dependent data **75**

4.1 Annual specific discharge 75
4.1.1 Description of time-dependent variables 75
4.1.2 Assessing the dimensionality of the system 76
4.1.3 Finding a robust model 80
4.1.4 Selecting a robust model for winter 83
4.1.5 Selecting a robust model for summer 88
4.1.6 Visualizing the effects of land cover change on annual runoff 92
4.2 Specific peak discharge 94
4.2.1 Description of some time-dependent variables employed 94
4.2.2 Selecting a robust model for winter 95
4.2.3 Selecting a robust model for summer 100

4.3 Specific volume of the annual peak event 105
4.4 Specific volume and total duration of high flows 109
4.5 Frequency of high flows 112

Chapter 5
Modelling characteristics of low-flows with time-dependent data **119**

5.1 Introduction 119
5.2 Description of time-dependent variables 120
5.3 Total drought duration 122

Chapter 6
An integrated approach to assess the impacts of climatic and land use/cover changes on the hydrological cycle at the mesoscale level **126**

6.1 Introduction 126
6.2 Model structure 127
6.2.1 A simple land use/cover change model 127
6.2.2 Stochastic simulation 130
6.3 Model implementation 132
6.3.1 Special Study Area 132
6.3.2 Calibration and validation of the LUCC model 133
6.4 Development scenarios for the Special Study Area 135
6.4.1 Socio-economic scenarios 135
6.4.2 Macroclimatic scenarios 138
6.4.3 Assembling the development scenarios 140
6.5 Simulation results 143

Chapter 7
Sensitivity analysis **148**

7.1 Introduction 148
7.2 Sensitivity of parameters to catchment size 148
7.3 Model sensitivity to a given parameter 150
7.4 Convergence of the Monte Carlo simulations 152

Chapter 8
Discussion and conclusions **154**

8.1 Discussion 154
8.2 Conclusions 158

References **159**
Appendix **171**