

---

# Contents

<b>1</b>	<b>Introduction</b> .....	<b>1</b>
	<b>References</b> .....	<b>11</b>
<b>2</b>	<b>Sequential decision models</b> .....	<b>15</b>
2.1	Exploitation of an exhaustible resource .....	16
2.2	Assessment and management of a renewable resource .....	17
2.3	Mitigation policies for carbon dioxide emissions .....	24
2.4	A trophic web and sustainable use values .....	27
2.5	A forestry management model .....	29
2.6	A single species age-classified model of fishing .....	31
2.7	Economic growth with an exhaustible natural resource .....	35
2.8	An exploited metapopulation and protected area .....	37
2.9	State space mathematical formulation .....	38
2.10	Open versus closed loop decisions .....	44
2.11	Decision tree and the "curse of the dimensionality" .....	46
	<b>References</b> .....	<b>47</b>
<b>3</b>	<b>Equilibrium and stability</b> .....	<b>51</b>
3.1	Equilibrium states and decisions .....	52
3.2	Some examples of equilibria .....	52
3.3	Maximum sustainable yield, private property, common property, open access equilibria .....	55
3.4	Stability of a stationary open loop equilibrium state .....	60
3.5	What about stability for MSE, PPE and CPE? .....	63
3.6	Open access, instability and extinction .....	66
3.7	Competition for a resource: coexistence <i>vs</i> exclusion .....	68
	<b>References</b> .....	<b>71</b>

**4 Viable sequential decisions** . . . . . 73

4.1 The viability problem . . . . . 75

4.2 Resource management examples under viability constraints . . . 76

4.3 The viability kernel . . . . . 80

4.4 Viability in the autonomous case . . . . . 83

4.5 Viable control of an invasive species . . . . . 86

4.6 Viable greenhouse gas mitigation . . . . . 89

4.7 A bioeconomic precautionary threshold . . . . . 90

4.8 The precautionary approach in fisheries management . . . . . 95

4.9 Viable forestry management . . . . . 98

4.10 Invariance or strong viability . . . . . 100

**References** . . . . . 105

**5 Optimal sequential decisions** . . . . . 107

5.1 Problem formulation . . . . . 108

5.2 Dynamic programming for the additive payoff case . . . . . 112

5.3 Intergenerational equity for a renewable resource . . . . . 115

5.4 Optimal depletion of an exhaustible resource . . . . . 117

5.5 Over-exploitation, extinction and inequity . . . . . 119

5.6 A cost-effective approach to CO<sub>2</sub> mitigation . . . . . 122

5.7 Discount factor and extraction path of an open pit mine . . . . . 125

5.8 Pontryaguin’s maximum principle for the additive case . . . . . 131

5.9 Hotelling rule . . . . . 134

5.10 Optimal management of a renewable resource . . . . . 136

5.11 The Green Golden rule approach . . . . . 139

5.12 Where conservation is optimal . . . . . 140

5.13 Chichilnisky approach for exhaustible resources . . . . . 141

5.14 The “maximin” approach . . . . . 144

5.15 Maximin for an exhaustible resource . . . . . 148

**References** . . . . . 151

**6 Sequential decisions under uncertainty** . . . . . 153

6.1 Uncertain dynamic control system . . . . . 154

6.2 Decisions, solution map and feedback strategies . . . . . 157

6.3 Probabilistic assumptions and expected value . . . . . 158

6.4 Decision criteria under uncertainty . . . . . 160

6.5 Management of multi-species harvests . . . . . 161

6.6 Robust agricultural land-use and diversification . . . . . 162

6.7 Mitigation policies for uncertain carbon dioxide emissions . . . . 163

6.8 Economic growth with an exhaustible natural resource . . . . . 166

**References** . . . . . 169

<b>7</b>	<b>Robust and stochastic viability</b> .....	171
7.1	The uncertain viability problem .....	172
7.2	The robust viability problem .....	172
7.3	Robust agricultural land-use and diversification .....	175
7.4	Sustainable management of marine ecosystems through protected areas: a coral reef case study .....	178
7.5	The stochastic viability problem .....	183
7.6	From PVA to CVA .....	185
	<b>References</b> .....	191
<b>8</b>	<b>Robust and stochastic optimization</b> .....	193
8.1	Dynamics, constraints, feedbacks and criteria .....	194
8.2	The robust optimality problem .....	195
8.3	The robust additive payoff case .....	196
8.4	Robust harvest of a renewable resource over two periods .....	199
8.5	The robust "maximin" approach .....	200
8.6	The stochastic optimality problem .....	201
8.7	Stochastic management of a renewable resource .....	205
8.8	Optimal expected land-use and specialization .....	210
8.9	Cost-effectiveness of grazing and bird community management in farmland .....	212
	<b>References</b> .....	219
<b>9</b>	<b>Sequential decision under imperfect information</b> .....	221
9.1	Intertemporal decision problem with imperfect observation .....	221
9.2	Value of information .....	225
9.3	Precautionary catches .....	225
9.4	Information effect in climate change mitigation .....	229
9.5	Monotone variation of the value of information and precautionary effect .....	231
9.6	Precautionary effect in climate change mitigation .....	233
	<b>References</b> .....	235
<b>A</b>	<b>Appendix. Mathematical Proofs</b> .....	237
A.1	Mathematical proofs of Chap. 3 .....	237
A.2	Mathematical proofs of Chap. 4 .....	239
A.3	Mathematical proofs of Chap. 5 .....	244
A.4	Robust and stochastic dynamic programming equations .....	248
A.5	Mathematical proofs of Chap. 7 .....	252
A.6	Mathematical proofs of Chap. 8 .....	253
A.7	Mathematical proofs of Chap. 9 .....	254
	<b>References</b> .....	259
	<b>Index</b> .....	261