

Soil Erosion Control in Drylands

Mohammad Jafari · Mohammad Tahmoures ·
Mohammad Ehteram · Majid Ghorbani ·
Fatemeh Panahi

Soil Erosion Control in Drylands

 Springer

Mohammad Jafari
Faculty of Natural Resources, College
of Agriculture and Natural Resources
University of Tehran
Tehran, Iran

Mohammad Ehteram
Department of Water Engineering
and Hydraulic Structures, Faculty of Civil
Engineering
Semnan University
Semnan, Iran

Fatemeh Panahi
Department of Desert Sciences
Engineering, Faculty of Natural Resources
and Earth Sciences
University of Kashan
Kashan, Iran

Mohammad Tahmoures
Soil Conservation and Watershed
Management Department, Zanzan
Agricultural and Natural Resource
Research Center
Agricultural Research, Education
and Extension Organization (AREEO)
Zanzan, Iran

Majid Ghorbani
Department of Life Sciences
University of Siena
Siena, Italy

ISBN 978-3-031-04858-6 ISBN 978-3-031-04859-3 (eBook)
<https://doi.org/10.1007/978-3-031-04859-3>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2022

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Illustrations by Dr. Siamak Panahi

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Soil erosion is one of the issues that has created many problems for human societies nowadays. Some of them include dam filling, blocking of railway lines, removal of fertile soils from irrigated and rainfed agricultural lands, loss of fertile (macro and micro) elements from the soils and most importantly the occurrence of terrible and dangerous floods which have killed thousands of people and left survivors homeless in addition to financial losses. Hygienic problems are also caused by erosion (especially by wind erosion) every year, which has received less attention. Soil erosion has caused problems not only in the agricultural sector but also in other sectors (such as industry, mining, health, oil, road construction, energy, environment, housing, military, etc.), and proposing such cases is the need for compensation of damages in some way. The issue of erosion and the methods of controlling and combating it are among the basic principles that have to be also taught in pre-university education. Two issues have to be considered: one is that it takes several hundred years to form 1 cm of soil, and the other is that billions of dollars are needed if we want to retrieve the lost soil by adding chemical fertilizers. Today, soil protection must be at the forefront of governments' management programs so that they do not face the very complex problems of soil erosion. All governments are looking for quick ways to control soil erosion, and this has led to widespread interest in the use of structural and engineering methods, however, the calculations and formulas related to the design of structures in this method are the result of studies and surveys conducted in different countries and generally the calibration of these calculations according to the natural and ecological conditions of arid and semi-arid regions has not received much attention. Also, during the construction of structures, the necessary supervision and monitoring are often not carried out by the relevant stakeholders and contractors, and the implementation of the structural method often imposes heavy costs on governments and organizations in charge of protecting the natural resources in the countries. Structural and engineering methods are often not compatible with nature, while the use of plants to combat various forms of erosion (splash, water, gully, river, tunnel, landslide, wind, etc.) is very cost-consuming and the durability of the biological control method of soil erosion would be much longer than the engineering method. Also, in the biological control method, different plant species can be used to

prevent the occurrence of erosion before it occurs. Of course, combining the structural and the biological methods can be of great assistance to the stability and effectiveness of the structural method in combating soil erosion. In combating wind erosion issue, it should be noted that combating wind erosion has been common in Iran in the past, and biochemical methods (combining plant cultivation using mulches, biological mulches which are compatible with environment) are of great importance in controlling this erosion and this method can be used to stabilize the inner and coastal sand dunes.

There is a great tendency to use vegetation in watershed management and erosion control projects in Iran due to the climate and plant diversity, as well as the abundance and different types of water and soil erosion. Lower cost and ecological adaptability have presented the advantage of using this method in sloping land stabilization and soil erosion control projects. Lack of adequate scientific sources in this field led the authors of this book to compile and conclude the results of recent studies and research on biological control of soil erosion and degradation and is mostly based on studies and projects, master's and doctoral dissertations and experiments of international researchers. It is hoped that the book will meet the needs of students and experts in the fields of soil protection, watershed management, natural resources and the environment, especially in arid and semi-arid regions around the world.

The generous assistance of M.A. Alireza Givar, Master of Philosophy of Art, Dr. Javad Momeni Damaneh, Ph.D. of Combating Desertification, M.Sc. Nazanin Azarnejad, Master of Rangeland management, M.A. Elaheh Lalehzadeh, Master of Architecture and M.A. Javad Attarha, Master of Combating Desertification improved the final outcome. We sincerely appreciate their help.

Tehran, Iran
Zanjan, Iran
Semnan, Iran
Siena, Italy
Kashan, Iran
February 2021

Mohammad Jafari
Mohammad Tahmoures
Mohammad Ehteram
Majid Ghorbani
Fatemeh Panahi

Contents

1	Soil Erosion: Factors, Processes and Effects	1
1.1	Introduction	1
1.2	Overview of the Effects of Soil Erosion	2
1.2.1	The Effects in the Eroded Area (Intra-Regional)	2
1.2.2	The Effects of Sediments in the Transport and Sedimentation Area (Extra-Regional)	3
1.2.3	Effect of Soil Erosion on Greenhouse Gases	5
1.2.4	Economic Losses of Soil Erosion	5
1.3	Soil Erosion: Factors and Processes	6
1.4	Effective Factors in Soil Erosion	6
1.4.1	The Effect of Climate on Soil Erosion	6
1.4.2	The Effect of Land Use and Vegetation on Soil Erosion	7
1.4.3	The Effect of Topography on Soil Erosion	9
1.4.4	The Effect of Soil Properties on Soil Erosion	11
1.4.5	The Effect of Human Activities on Soil Erosion	12
1.5	Intra-Regional Effects of Soil Erosion	15
1.5.1	Erosion and Soil Quality	16
1.6	Extra-Regional Effects of Soil Erosion	18
1.6.1	Intra-Regional Control of Non-point Pollutants	19
1.7	Global Effects of Soil Erosion	20
1.7.1	Soil Carbon Storage and Its Changes	21
1.7.2	Soil Erosion and Carbon Fluctuations	23
1.7.3	Study of Soil Carbon Loss at Different Scales	25
1.7.4	Soil Carbon Sequestration and Protection	27
1.8	Economic Effects of Soil Erosion	27
	References	29
2	The Role of Vegetation in Confronting Erosion and Degradation of Soil and Land	33
2.1	Introduction	33

2.2	Definition of Bioengineering	34
2.3	History	35
2.4	Literature Review of Research Conducted	37
2.5	Concepts and Terms	39
2.5.1	Soil Cohesion	39
2.5.2	Internal Friction Angle	39
2.5.3	Stress	39
2.5.4	Shear Stress	39
2.5.5	Shear Strength	39
2.5.6	Normal Stress	40
2.5.7	Soil Shear Strength	40
2.5.8	Slope Safety or Stability Factors	40
2.5.9	Analysis of Slope Stability	41
2.6	Methods for Measuring Soil Shear Strength (Without Root)	41
2.6.1	Direct Shear Box Test	41
2.6.2	Methods for Measuring the Shear Strength of Soil Containing Plants Roots	43
2.7	Effect of Vegetation on Slope Stability	46
2.7.1	Effect of Vegetation on Prevention and Control of Surface Erosion	46
2.7.2	Effect of Plants on Prevention and Control of Streambank Erosion	48
2.7.3	Effect of Vegetation on Prevention and Control of Soil and Land Mass Movements	49
2.7.4	Effect of Vegetation on Slope Stability	50
2.7.5	Effect of Plants Roots on Slope Stability	50
2.7.6	Effect of Branches and Leaves on Slope Stability	52
2.7.7	Negative Effects of Vegetation Cover on Steep Slope Stability	53
2.8	Effect of Plants Vegetative Form on Erosion Prevention and Control	54
2.9	Effect of Woody Vegetation on Soil Mass Stability	57
2.10	Range of Plant Root Effect on Soil Mass Stabilization	57
2.10.1	The Main Roots and Their Depth of Penetration into the Soil	57
2.10.2	Effect of Tensile Strands and Plant Roots on Shear Strength of Soil	58
2.10.3	Infinite Slope Analysis	60
2.10.4	Effect of Root Mechanical and Compressive Force on Slope Stability	62
2.11	Effect of Plant Species and Management of Vegetation Restoration Projects on Slope Stability	62
2.11.1	Plant Successional Changes	62
2.11.2	Functional Roles of Vegetation in Combating and Controlling Erosion	63

2.12	Evaluation of Habitat	64
2.12.1	Landscape	65
2.12.2	Protection Designs	65
2.12.3	Vegetation of Surrounding Lands	65
2.12.4	Drainage Properties	65
2.12.5	Soil Structure and Fertility	65
2.12.6	Seed Quantity and Composition	66
2.12.7	Landscape Design	67
2.13	Selection of Plant Species	67
2.13.1	Selection Methods	67
2.13.2	Performing Tests	69
2.13.3	Cultivation Methods	69
2.13.4	Management and Monitoring	71
2.14	Root Growth and Moisture Needed for Trees and Other Vegetative Types	72
2.14.1	Root Growth	72
2.14.2	Moisture Movement in Soil	73
2.14.3	Surface Maintenance on Soil	74
2.14.4	Relative Amount of Precipitation Received	75
2.15	Methods of Plant Vegetation Establishment on Steep Slopes	75
2.15.1	Root Properties in Slope Stabilization Design	75
2.15.2	General Principles of Slope Stability	75
2.15.3	Application of <i>Robinia Pseudoacacia</i> to Stabilize Slopes	76
2.15.4	Root Properties	77
2.16	Further Developments in Engineering and Stabilization of Slopes with Vegetation	78
2.16.1	Advances in Eco-Engineering	79
2.16.2	Signs of the Past	81
2.16.3	Regions	81
2.16.4	Tropical Regions	82
2.16.5	Organizational Aspects	83
2.16.6	Organizing Eco-Engineering Projects	83
2.16.7	Insurance by Multilateral Foundations and NGOs	83
2.16.8	Future-Design	84
2.16.9	Methods	84
2.16.10	Aspects of Project Management and Contracting in the Future	85
2.16.11	Research	85
2.16.12	Computer Modeling	87
2.16.13	Further Effects and Future Objectives Trend	88
2.16.14	Eco-Engineering Environmental Classification and Database	89
2.16.15	Marginal Discoveries and Innovations	89

2.16.16	Costs	90
2.16.17	Summary	90
2.17	The Role of Plants in Refining Soil Contamination	92
2.17.1	Definition of Phytoremediation of Soil	93
2.17.2	History of Phytoremediation	94
2.17.3	Advantages and Disadvantages of Phytoremediation	95
2.17.4	Contamination Refining Methods	95
2.17.5	Plant Mechanisms for Soil Detoxification	96
2.17.6	The Role of Root Secretion in Soil Detoxification	97
2.17.7	Modification Materials and Increased Absorption Efficiency of Heavy Metals in the Plant	98
2.17.8	Phytoremediation Methods	98
2.17.9	Mechanism of Organic Remedies Solubility in Phytoabsorption	102
2.17.10	Application of Mineral Agents to Increase Phytoabsorption	103
2.17.11	Types of Contamination	104
2.17.12	Phytoremediation of Petroleum Contaminants	109
2.17.13	Decomposition of Petroleum Contaminants	109
2.17.14	Effect of Plant Root Exudate on Soil Refining	112
2.17.15	Plant Roles in the Bioavailability of Petroleum Contaminants	114
2.17.16	Plant Roles in Increasing the Genes Affecting Contaminant Degradation	115
2.18	Examples of Species Studied for Phytoremediation	127
2.19	Water Harvesting in Arid Lands	132
2.19.1	Introduction	132
2.19.2	Rainwater Harvesting Techniques	132
2.19.3	Choosing the Method for Water Harvesting	134
	References	135
3	Biological Control of Water Erosion	143
3.1	Management Measures and Biomechanical Operations in Watershed	143
3.1.1	Biological Methods of Preventing and Combating Soil Erosion	143
3.1.2	Management Measures	145
3.1.3	Plowing Modification	145
3.1.4	Protection and Exclusion	146
3.1.5	Exclusion Objectives	146
3.1.6	Land Use Improvement	147
3.1.7	Preserving Vegetation and Soil Humus	153

3.2	Biological Operations	153
3.2.1	The Reasons of Superiority for Biological Control of Soil Erosion Rather Than Mechanical (Structural) Methods	155
3.2.2	Selection of Suitable Plants for Soil Conservation	158
3.2.3	Plant Resistance to Pests and Diseases	161
3.3	Biological Operations	164
3.3.1	Rangeland Management	165
3.3.2	Selection of Proper Species for Rangeland Management	168
3.3.3	Properly Preparation of the Soil and Seed Bed	170
3.3.4	Seeding	172
3.3.5	Seeding and Its Different Types	172
3.3.6	Interseeding	183
3.3.7	Cultivation of Rangeland and Forage Plants and Creating Pasture	185
3.3.8	Crop Rotation	188
3.3.9	Rainfed Agriculture	197
3.3.10	Raun Kaier's Method	209
3.3.11	Classification of Pabot	210
3.3.12	Classification Based on the Precipitation Amount	211
3.3.13	Other Classification Methods	212
3.3.14	Plant Species Suitable for Different Vegetation Zones in Iran	213
3.3.15	Shrub Planting	224
3.3.16	Mount Culture	225
3.3.17	Breeding and Preparation of Seedlings	229
3.3.18	Increased Soil Moisture Storage for Planting Seedlings	247
3.3.19	Evaporation Control	252
3.3.20	Cuttings, Stool Shoots and Root Suckers	253
3.3.21	Fertilizing Rangeland	257
3.3.22	Stabilization of Sloping Lands by Plants	260
3.3.23	Buffer Protection Areas	263
3.4	Suitable Plants for Biological Control of Soil Erosion and Vegetation Restoration in Semi-arid Regions	265
3.4.1	The Issues of Semi-arid Regions	265
3.4.2	Suitable Plants for Biological Control of Soil Erosion and Rangeland Restoration in Semi-arid Regions	266
3.4.3	Suitable Plants for Semi-arid Regions with an Average Annual Rainfall of 300–350 mm	267
3.4.4	Suitable Plants for Semi-arid Regions with Average Annual Rainfall of 350–500 mm	272

- 3.4.5 Suitable Plants for Semi-arid Regions with an Average Annual Rainfall of More Than 500 mm 273
- 3.5 Vegetative Mulching 274
- 3.6 Biological Control of Gully Erosion 275
 - 3.6.1 Method to Control Gully Erosion 275
 - 3.6.2 Characteristics of Suitable Plants for Biological Control of Gully Erosion 276
 - 3.6.3 Important and Suitable Plants for Prevention, Control, and Combating Against Gully Erosion 277
- 3.7 Biological Control of Tunnel Erosion (Dissolution Erosion) 285
 - 3.7.1 Appropriate Methods for Biological Control of Tunnel Erosion and Created Gullies 286
- 3.8 Biological Control of Stream and River Erosions 288
 - 3.8.1 Causes of Destruction in Riversides 288
 - 3.8.2 The Methods of Biological Control of Lateral Erosion 289
- 3.9 Protecting the Structure of Earthen Dam and Beaches of Seas and Lakes Using Plants 294
- References 295
- 4 Wind Erosion Biological Control 297**
 - 4.1 Direct Control 297
 - 4.2 Indirect Control 298
 - 4.3 Methods for Preservation and Regeneration of Vegetation in Deserts 298
 - 4.3.1 Role of Proper Methods in Water Resources Exploitation and Irrigation for Regenerating Vegetation in Deserts 299
 - 4.3.2 Correct Irrigation Methods in Deserts 299
 - 4.3.3 Appropriate Agricultural Approaches for Maintaining and Regenerating of Deserts' Vegetation 308
 - 4.3.4 Vegetation Management 312
 - 4.4 Seedling Planting in Arid and Desert Regions 315
 - 4.4.1 Seeding Planting Objectives 315
 - 4.4.2 The Effect of Seedling on Preventing Wind Erosion 317
 - 4.4.3 The Role of Seedling in Creating Desired Conditions for Strengthening Vegetation 318
 - 4.4.4 The Role of Seedling in Minimizing Wind Erosion 319
 - 4.4.5 The Role of Seedling in Forming Windbreaks 319
 - 4.4.6 Windbreak Types and Their Properties 320
 - 4.4.7 The Role of Seedling and Forestry in Production and Supply of Plant Fuels 329

4.4.8	The Role of Seedling in Beautification of the Environment and Promenade	329
4.4.9	Seeding Process	332
4.4.10	Seedling Planting Practices	342
4.4.11	Different Forms of Seedlings Planting in Sand Dunes	343
4.5	Seeding in Arid and Desert Regions	347
4.5.1	Seeding Objectives	347
4.5.2	Seeding Costs	348
4.5.3	Seed Identification	349
4.5.4	Adapted Plant Species Suitable for Cultivation in Arid and Desert Regions	351
4.5.5	Seed Consumption in Arid and Semi-arid Regions	356
4.5.6	Effective Factors on Seeding	358
4.5.7	Proper Seeding Time	363
4.5.8	Proper Depth of Seeding	364
4.5.9	Proper Land and Seed Bed Preparation in Arid and Desert Regions Correctly	364
4.5.10	Suitable Regions for Seeding	366
4.5.11	Seeding in Saline Lands	367
4.5.12	Seeding Practices	369
4.5.13	Transplanting	371
4.5.14	How to Sow Seed in Desert Areas	371
4.5.15	Types of Seed Sowing	372
4.5.16	Piling	373
4.5.17	Care and Irrigation of Seeding and Seed Sowing Regions in Arid and Desert Areas: Applicable Methods	374
4.6	Mulch and Mulching in Arid and Desert Areas	377
4.7	Plants in Deserts of Iran	378
4.8	Coastal Sand Dune Stabilization Methods	393
4.8.1	Planting Pot Seedlings	396
4.8.2	Characteristics of Plants Suitable for Biological Soil Erosion Control in Drylands and Sand Dunes	396
4.8.3	Characteristics of Some of the Most Important Plants Suitable for Biological Soil Erosion Control in Arid and Desert Areas	397
	References	398
5	Biological and Biomechanical Methods for Stream Stabilization	401
5.1	Introduction	401
5.2	Advantages of Biotechnical Methods	404
5.3	Role of Plants in Riverside	405
5.4	Role of Plants in Slope Stability of Stream Side	406
5.5	Structural Bioengineering Methods in Vulnerable Areas	409

- 5.6 Basic Requirements for Natural Slope Construction 411
 - 5.6.1 Analysis of Safety Measures and Preferred Solutions 412
- 5.7 Methods of Stabilizing the Slope of Streams and Rivers Walls ... 412
- 5.8 Slope of Landslides 413
- 5.9 Gabion with Planting and Reproduction with Cuttings 413
- 5.10 Sample Projects 414
- 5.11 Criterion of Selecting Construction Methods Using Living Plant Materials 414
- 5.12 Biomechanical Structures to Combat and Inhibit a Variety of Water Erosion in Drained Lands 416
- 5.13 Transversal Constructions 434
- 5.14 Longitudinal Constructions 437
 - 5.14.1 Groins 437
- 5.15 Log Bush Barriers 441
- References 443

- 6 Slope Stabilization Methods Using Biological and Biomechanical Measures 445**
 - 6.1 Introduction 445
 - 6.2 Some Presented Principles for Biological Control of Soil Erosion 452
 - 6.3 Plant Properties for Soil Conservation and Erosion Control 454
 - 6.3.1 Choosing Appropriate Plants for Soil Conservation 455
 - 6.3.2 Field Choose 459
 - 6.3.3 Field Preparation 459
 - 6.3.4 Rainfall Harvesting and Surface Runoff Control 459
 - 6.3.5 Temporary Stabilization of Plant Beds 460
 - 6.3.6 The Methods of Saplings Transplantation to Natural Fields 462
 - 6.3.7 Propagating 466
 - 6.3.8 The Method of Sapling Conservation 466
 - 6.4 The Stabilization of Steep Lands by Means of Plants 469
 - 6.4.1 Plant Root System and Evapotranspiration 469
 - 6.4.2 Evapotranspiration and Its Effects on Soil Moisture 471
 - 6.4.3 Plantation on Steep Slopes 471
 - 6.5 The Usage of Plants for Gully Erosion Control 472
 - 6.5.1 Gully Erosion Control with Permanent Enclosure 473
 - 6.5.2 The Characteristics of Appropriate Plants for Biological Gully Erosion Control 473
 - 6.5.3 Important and Appropriate Plants for Gully Erosion Control and Prevention 474
 - 6.5.4 Gully Erosion Control by Means of Biological Control Without Enclosure 481
 - 6.6 Tunnel Erosion Control 482

6.6.1	Appropriate Biological Methods for Tunnel and Gully Erosion Control	482
6.7	Bank Erosion Biological Control	483
6.7.1	The Causes of Land Degradation in River Margin	484
6.7.2	Bank Erosion Control	485
6.7.3	Protective and Retaining Living Walls	485
6.7.4	Living Protector on the Steep Surface of River Side	485
6.7.5	Short Living Lateral Obstacles for Bank Erosion Control	486
6.7.6	Propagating and Planting Rooted Saplings in Floodways or River Margins	487
6.7.7	Making Use of Tree Trunks for Rivers Margin Land Conservation	487
6.7.8	Wire Screen Dead Parapets and Plantation	487
6.7.9	Meander Course Reformation	488
6.7.10	Conservation of Body Structure of Soiled Dams and Sea and Lake Coasts	489
6.7.11	Combating Intrusive Plants, Pruning Excess Plant Jumps in River Margins	490
6.8	Appropriate Plants for Biological Control of Soil Erosion in Semi-arid Regions and Plant Cover Restoration	490
6.8.1	Introducing Appropriate Plants for Regions Which Have 180–350 mm/year Rainfall	493
6.8.2	Appropriate Plants for Regions with 350–500 mm Precipitation Per year	497
6.8.3	Appropriate Plants for Regions with More Than 500 mm Rainfall	498
6.9	Appropriate Plants for Biological Soil Erosion Control in Arid Regions and Plant Cover Revitalization	499
6.10	Costal Dune Stabilization	501
6.11	Sand Dune Stabilization	502
6.12	Engineering and Mechanical Methods	502
6.13	Chemical Methods	503
6.14	Planting Potted Plants	504
6.15	The Properties of Plants Appropriate for Plant Cover Rehabilitation in Arid Regions	504
6.15.1	Appropriate Plants for Biological Soil Erosion Control	504
6.16	Introducing Significant and Appropriate Plants for Soil Erosion Control and Plant Cover Rehabilitation in Arid Regions	505
6.17	Ground Bioengineering Systems	506
6.17.1	Function and Effects	506
6.17.2	Biological Building Materials	506
6.17.3	Species Selection	507

- 6.17.4 Vegetation Systems and Plant Origin 510
- 6.17.5 Plant Propagation 510
- 6.17.6 Preliminary Works 512
- 6.17.7 Selection of the Method and Type of Construction 539
- 6.17.8 Construction Timing 540
- 6.17.9 Limits of Application 540
- 6.17.10 Construction Costs 540
- 6.18 Revegetation of Slopes by Surface Protection with Living Material 542
 - 6.18.1 Bush Mattress Construction (Bush Matting Construction) Procedure 543
 - 6.18.2 Materials 544
 - 6.18.3 Ecological and Technical Effectiveness 544
 - 6.18.4 Sodding (Turfging) 544
 - 6.18.5 Dry Seeding 545
 - 6.18.6 Mulch Seeding 545
 - 6.18.7 The Schiechteln Method (Mulch Seeding with Long Fiber Material) Procedure 546
 - 6.18.8 Placing of Seed Mats 547
 - 6.18.9 Placing of Concrete Blocks with Seeds 547
- 6.19 Methods for Stabilizing Sloping Lands Adjoining Urban and Suburban Areas with Arid and Semi-Arid Climates Using Biological and Biomechanical Measures 548
 - 6.19.1 Introducing Some Drought Tolerant Plant Species for Highway Margin Landscaping 549
 - 6.19.2 Plant Characteristics Suitable for Vegetation Reclamation in Arid and Desert Areas and Highway Margins 551
 - 6.19.3 Suitable Plant Species for Landscaping Highway Margin 553
- 6.20 Slope Stabilization Methods Using Living Materials 582
 - 6.20.1 Wattle (Wicker) Fences 583
 - 6.20.2 Cordon Construction 584
 - 6.20.3 Bush Wattles or Slope Fascines 586
 - 6.20.4 Groove (Furrow) Construction 587
 - 6.20.5 Hedge Layer Construction Procedure 589
 - 6.20.6 Bush Layer Construction 590
 - 6.20.7 Hedge Bush Layer Construction 594
 - 6.20.8 Placing of Cuttings, Including Wall Joint Planting 594
- 6.21 Slope Stabilization by the Combined Use of Living and Non-living Materials 595
 - 6.21.1 Crib Wall Construction with Branch Layering Wooden Crib Wall 595
 - 6.21.2 Metal Crib Walls Constructed from Prefabricated Elements 598

6.21.3	Vegetated Stone Walls and Rock Piles (Without Mortar)	598
6.21.4	Vegetated Hard Gabions	599
6.21.5	Soft Gabions	600
6.21.6	Live Slope Gratings	602
6.21.7	Lattice Construction	603
6.21.8	Vegetated Palisade and Pole Construction	605
6.21.9	Living Branch Layering of Gullies	606
6.22	Biotechnical Drainage Systems	606
6.22.1	Drainage by Using Pumping Plant Species (Phreatophytes)	606
6.22.2	Grassed Waterways	607
6.22.3	Live Fascine Drains	608
6.22.4	Gravel Drains	611
6.23	The Use of Geotextiles	612
6.23.1	The Role of Geotextiles in Water Erosion Control	614
6.23.2	Effects of Geotextiles on Hydrology	616
6.23.3	Effects of Geotextiles on Soil Strength	619
6.23.4	The Role of Geotextiles in Wind Erosion Control	620
6.23.5	The Role of Geotextiles in Vegetation Establishment	621
6.23.6	Effects of Geotextiles on Microclimate	622
6.23.7	Effects of Geotextiles on Soil Conditions for Vegetation Establishment and Growth	623
6.23.8	Comparisons Between Mulches and Geotextiles	624
6.23.9	Care and Maintenance of Bioengineering Structures	625
6.24	Rangeland Soil Management	629
6.24.1	The Effects of Grazing on Rangeland Soils	629
6.24.2	The Effect of Plant Covers on Rangeland Soils	632
6.24.3	Rangeland Soil Restoration	632
6.24.4	Organic Material and Soil Fertility	634
6.24.5	The Cycle of Plant and Soil Organic Materials in Agroforestry	634
6.24.6	The Effects of Plant Cover on Slope Stability	635
6.25	Agroforestry	636
6.25.1	Different Kinds of Agroforestry Systems	637
6.25.2	Trees and Water Cycle	639
6.25.3	Agroforestry Systems for Water Management	640
6.25.4	Agroforestry and Soil Conservation	642

6.25.5	Using Agroforestry System by Making Use of Trees to Control Erosion and Reform Existing Condition	642
6.25.6	Advantages of Agroforestry System	643
	References	644
7	Agroforestry and Its Role in Soil Erosion Biological Control	649
7.1	Integrated Land Use (Agroforestry)	649
7.2	The Concept of Agroforestry	650
7.3	The History of Agroforestry and Its Current Situation in the World	651
7.4	Agroforestry Situation in Iran	651
7.4.1	Agroforestry Systems in Caspian Region	652
7.4.2	Agroforestry Systems in the Arasbaran Region	652
7.4.3	Agroforestry Systems in Zagros Region	652
7.4.4	Agroforestry Systems in Irano–Turanian Region	653
7.4.5	Agroforestry Systems in Gulf-Oman Region	653
7.5	Benefits of Agroforestry	654
7.5.1	Ecological Benefits	654
7.5.2	Economic Benefits	654
7.5.3	Social Benefits	654
7.6	Restrictions of Agroforestry	654
7.6.1	Environmental Perspective	655
7.6.2	Socioeconomic Perspective	655
7.7	Measures for Soil Modification in Agroforestry Operations	655
7.8	Selection of Tree Species	656
7.8.1	Suitable Tree Species for Wetlands	656
7.8.2	Selection of the Crop	657
7.9	Types of Agroforestry Systems	657
7.9.1	Periodic Cultivation	657
7.9.2	Tree Fallow	657
7.9.3	Intermediation Cultivation (Cultivation of Non-crop Plants Among Crops)	657
7.9.4	Tongya	658
7.9.5	Trees in the Arable Lands	658
7.9.6	Multilevel System	658
7.9.7	Marginal Cultivations	658
7.9.8	Trees as Buildings to Control Erosion	658
7.9.9	Windbreak and Wildlife Shield	659
7.9.10	Row Intermediation Cultivation	659
7.9.11	Strips on the Contour Lines	659
7.9.12	Trees in Rangeland	659
7.9.13	Live Rows and Hedges	659
7.10	Multipurpose Trees in Agroforestry	660
7.10.1	Benefits of Multipurpose Trees	661

7.10.2	Properties of Multipurpose Trees Suitable for Agroforestry	662
7.10.3	Trees for Forage Production	663
7.10.4	Nitrogen-Fixing Trees	663
7.10.5	Suitable Trees for Fuel Wood Production	664
7.11	General Principles for the Management of Multipurpose Trees	668
7.12	Management of Agroforestry System	670
7.12.1	Primary Distance of Trees	671
7.12.2	Pruning Type and Time	672
7.12.3	The Amount and Time of Pruning	673
7.13	Interactions of Trees and Crops	677
7.13.1	The Interaction Effects	678
7.13.2	Benefits of Studying Tree-Crop Interactions	678
7.13.3	Required Information to Collect from Tree-Crop Interactions	679
7.13.4	The Obvious Effects of Stresses on the Plant	679
7.13.5	Environmental Factors in Agroforestry	680
7.13.6	The Role of Environment in Agroforestry Systems	680
7.13.7	The Environment and Tree-Crop Interactions	681
7.13.8	Physical Environmental Factors	681
7.14	Aspects of Soil Productivity in Agroforestry	681
7.14.1	Soil Improvement Mechanisms in Agroforestry	683
7.14.2	Effects of Trees on the Site Soil	684
7.14.3	Effects of Trees on Their Productivity Soil Conservation	685
7.14.4	Physical Conditions of Soil	687
7.14.5	Soil Conservation and Agroforestry	692
7.14.6	Benefits of Agroforestry Systems	693
7.15	The Role of <i>Haloxylon</i> in Agroforestry	694
7.15.1	Botanical Specifications of <i>Haloxylon</i>	694
7.15.2	<i>Haloxylon</i> Cultivation	695
7.15.3	Site	695
7.15.4	The Role of <i>Haloxylon</i> as Windbreak in Agroforestry	696
7.15.5	The Methods of <i>Haloxylon</i> Cultivation	696
7.15.6	Impacts of <i>Haloxylon</i> on Some Physical and Chemical Properties of Soil	697
7.15.7	The Role of <i>Haloxylon</i> in the Integrated Management of Pests and Diseases	698
7.15.8	The Socio-economic Impacts of <i>Haloxylon</i>	699
7.15.9	Importance of <i>Haloxylon</i> in Soil Conservation	699
	References	700