

Mangroves and Halophytes
Restoration and Utilisation

edited by

Helmut Lieth, Máximo García Sucre and Brigitte Herzog



MANGROVES AND HALOPHYTES: RESTORATION AND UTILISATION

Tasks for Vegetation Sciences 43

SERIES EDITOR

H. Lieth, *University of Osnabrueck, Germany*

The titles published in the series are listed at the end of this volume

Mangroves and Halophytes: Restoration and Utilisation

Edited by

HELMUT LIETH

*Institute of Environmental Systems Research
University of Osnabrueck
D-49069 Osnabrueck
Germany*

MAXÍMO GARCÍA SUCRE

IVIC (Instituto Venezolano de Investigaciones Cientificas)
Apto.21827, Caracas 1020-A, Venezuela

and

BRIGITTE HERZOG

*OSTRin i.R Justinus-Kerner-Gymnasium
74189 Weinsberg
Germany*

 Springer



A C.I.P. catalogue record for this book is available from the Library of Congress

ISBN 978-1-4020-6719-8 (HB)
ISBN 978-1-4020-6720-4 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands

www.springer.com

Printed on acid-free paper

All Rights Reserved

© 2008 Springer Science + Business Media B.V.

No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission from the Publisher, with the exception of any material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work.

Foreword

Foreword by the Editor of the T:VS Series, Volume 43

Helmut Lieth
Prof. em. University of Osnabrueck
Prof. h.c. Uzbek Academy of Sciences,
IWP Tashkent

During 2005 the editors of this volume started to enlarge the work of the international society of halophytes utilisation (ISHU) from their previous concentration of the Old World to include also the New World. In this region the main interests on halophytes were reported from North America. We had already used a number of species from this region in the field experiments of the ISHU projects around the Mediterranean Sea, but little was known about the performance of these species in South America. Some of our members were interested in using species from this region in other areas of the world, but before doing so they wanted more information about the performance of these species in competition with native plants in the new environments.

From the South American regions one of the editors (Lieth) had long time experiences with salinity problems and had worked with scientists in Venezuela and Colombia. Other members of the ISHU group of scientists had interest in starting projects in the region as well. It was therefore convenient for the entire group to renew the contacts with the scientists from this region, although the working conditions as well as the political environment had drastically changed.

With the help of our old friends and the generous help of the DAAD section for South America, it was

possible to develop in 2005 the cooperation with the ecological section of IVIC in Venezuela. The new political and public awareness situation in Venezuela made it possible for the new director of IVIC, Dr. M. Garcia-Sucre, to establish international cooperation on the coastal ecosystems protection, which was needed because of the heavy impact the oil and gas pipelines had inflicted upon several of the mangrove ecosystems as well of the inland semidry areas.

Several members of the European ISHU and several Venezuelan colleagues contributed to the seminars in IVIC/Caracas and several German Universities in Osnabrueck, Giessen, Bremen and Hanover. This volume compiles the papers presented at these meetings as well as contributions which were triggered by these seminars.

It was advantageous for the work on this volume that OSTRin Brigitte Herzog agreed to cooperate with the other members of the group on the seminars as well as in the publication of the volume. She had previous contact with several persons in Venezuela and with some of the persons contributing to the volume from Germany.

We thank all foundations and private individuals who contributed to the project and made it possible to link their work, mostly done in countries of the Old World, with projects of interest to the New World.

Opening of the Seminars

Expectations from the Workshop with Regard to the Utilisation of Mangroves and Halophytes in Venezuela, in the Coastal Regions as well as for Inland Agriculture on Saline Soils

by M. García Sucre

It is currently believed that the possibility of using the saline soils in agriculture in order to prevent famine in the developing countries remains remote. Even the conservation of mangroves has received little attention in the Caribbean region. If we start to work from now on these problems, we will have scientific and technical solutions for them in 10 years, presumably. How many people will live in the Caribbean countries in the next decade? At the rate of the mean growing population, we will have at least 40% more people to feed. Yet, the production of food is even today an unsolved problem in the majority of these countries. This is the case in Latin America, not to speak of Africa and some regions of Asia. Thus, the task of working in the utilisation for the production of food in soils that are now useless for that purpose seems to us of an overwhelming importance.

Venezuela is not an exception concerning the problem of food production. In this concern, one of the priorities of the Government of Venezuela is to promote what has been called *Seguridad Alimentaria* in our country. Along this line we decided to organise two workshops on 'Rehabilitation of mangroves and sustainable utilisation of halophytes', one in January 2006 at the Instituto Venezolano de Investigaciones Científicas (IVIC) in Venezuela, and the other in May 2006 at the University of Osnabrueck in Germany. Needless to say, the vision, dynamism and enthusiasm

of Professor Helmut Lieth contributed greatly to the success of both scientific events.

'Rehabilitation and sustainable use of mangrove and halophytic ecosystems in Venezuela' has been one of the topics of these workshops. The state of the art in the knowledge of halophytic systems in Venezuela, the necessity of their conservation, the reclamation of soil affected by salinity and the possible strategies for their rehabilitation and sustainable use were discussed. Three projects were defined during the round table discussions: two for the coastal regions concerning the rehabilitation and sustainable use of mangrove ecosystems, and a third project for the inland, concerning the use of halophytes for the rehabilitation of soils affected by salinity as a consequence of using inadequate agricultural techniques. These projects were elaborated in collaboration with Professor Lieth, and adapted to the requirements of *Misión Ciencia* (an initiative of the Government of Venezuela in order to promote the development of science with emphasis on applied problems).

The projects for the coastal regions are the rehabilitation and creation of mangrove areas for their sustainable use in the sectors of Buche-Playa Los Totumos (Miranda State), Parque Nacional Morrocoy and the Vela de Coro (Falcón State), respectively. These three coastal sectors show evidence of inadequate environmental management. The laboratory of Ecology and

Genetics of Populations, the laboratory of Ecology of Soils of the Centre of Ecology of IVIC and the laboratory of Vegetation Ecology of the Central University of Venezuela will work on these projects in collaboration with the University of Osnabrueck. Specialists in the use of halophytes for conservation and management of saline ecosystems of other institutions are expected to contribute to these projects.

Some important benefits could be obtained from the realisation of these projects in the two regions of Venezuela. An increase of the mangrove areas could diminish the coastal erosion (which is important in the mentioned areas), and will improve the quality of air. Also an increase in complexity of the mangroves could favour the growing of species usually associated with these systems. This in turn could increase a sustainable fishery industry, which could favour the incoming population living in the neighbourhoods. From the social point of view these communities will be informed about conserving and producing benefits from mangroves in a sustainable way. Furthermore, these projects have an intrinsic scientific and teaching interest since the mentioned coastal regions can be considered as natural laboratories. Finally, educational tourism could also be an additional source of economical benefit.

The last project is addressed to the inland occidental central region of Venezuela. It concerns the use of

halophytes for the rehabilitation of soils affected by salinity as a consequence of using inadequate agricultural techniques. Special attention will be given to the Valle de Quibor in Lara State. For the horticulture system in this valley, an excess of mechanisation and of saline water has been used. The farming of onions, tomatoes and melons are particularly extensive in this valley (about 5,000 ha).

This problem will be attacked in six steps:

1. Measures of the degree of salinity, quality of soils and water
2. Selection of the appropriate halophytes species
3. Pilot studies in farms
4. Chemical analysis to establish to which degree the halophytes are producing the expected result
5. Evaluation of the quality of the recuperated soils
6. Palatability proofs and protein efficiency of the halophytes to nourish livestock

I thank the participants of this workshop for giving me the opportunity to learn about the production of food and environmental conservation that can be useful for the Caribbean region.

Dr. Maximo Garcia Sucre, director IVIC
Apto. 21827 Caracas 1020-A
Venezuela

Table of Contents

Foreword	v
Foreword by the Editor of the T:VS Series Helmut Lieth	
Opening of the Seminars	vii
M. García Sucre	
Contributors	xi
List of Legends for the Colored Plates	xiii
List of Tables	xvii
Color Plates	xix
Part I General Aspects	
1 Concepts for Different Uses of Halophytes	3
Helmut Lieth	
2 Global Water Crisis: The Potential of Cash Crop Halophytes to Reduce the Dilemma	7
Hans-Werner Koyro and Helmut Lieth	
3 Present Efforts to Develop Sustainable Saline Production Systems	21
Helmut Lieth	
4 Studies on Halophytes and Salinity Problems in Mediterranean Agriculture	25
Belligno A. and Sardo V.	
Part II Saline Ecosystems in Venezuela	
5 Investigations Proposed in Venezuela for the Development of Systems for the Sustainable Utilisation of Halophytes, in the Context of International Development	33
Helmut Lieth and Brigitte Herzog	

6	Diagnostics About the State of Mangroves in Venezuela: Case Studies from the National Park Morrocoy and Wildlife Refuge Cuare	51
	Maria Beatriz Barreto	
7	Contribution of Seagrass Ecosystems to the Venezuelan Coastline Vegetation.	65
	Beatriz E. Vera Vegas	
Part III Experimental Systems		
8	Comparative Biochemical Study of the Rhizosphere of <i>Rhizophora mangle</i> and its Associated Species <i>Cyperus</i> sp. in the Ciénaga de Soledad (Colombia)	79
	Jorge E. Paolini and Luz Esther Sánchez-Arias	
9	Creation of Mangrove “Productive Oases”: Community Participation for the Sustainable Utilization of Halophytes	85
	Luz Esther Sánchez-Arias and Jon Paul Rodríguez	
10	Mangrove Restoration in a Tropical Semiarid Environment: A Case Study in Landscape Design	97
	Rosario Fraino de Pannier and Federico Pannier	
11	Mangrove Establishment on Artificial Islands: A Case Study	109
	Federico Pannier and Rosario Fraino de Pannier	
12	The Effect of Temperature on the Accumulation of Salts and Chromium in Seedlings of <i>Avicennia germinans</i> (“Mangle Salado”) and <i>Rhizophora mangle</i> (“Mangle Rojo”) Exposed to Tannery Wastewaters	119
	Luz Esther Sánchez-Arias and Augusto Ruiz Castro	
13	Salt Tolerance of <i>Chenopodium quinoa</i> Willd., Grains of the Andes: Influence of Salinity on Biomass Production, Yield, Composition of Reserves in the Seeds, Water and Solute Relations.	133
	Hans-Werner Koyro, Sayed Said Eisa, and Helmut Lieth	
14	Biosaline Biomass for Energy, a Solution for Saline Wastelands	147
	Jeannette Hoek	
Index		155

Contributors

M.B. Barreto
Instituto Zoología Tropical, Facultad de Ciencias,
Universidad Central de Venezuela, Caracas,
Venezuela, e-mail: manglerojo@gmail.com

A. Belligno
Department of Agricultural Engineering, University
of Catania, Via Valdisavoia,
5 – 95123 Catania, Italy

B. Böer
UNESCO Regional Office in the Arabic State of
Gulf, Doha, Qatar
e-mail: habitat_international@hotmail.com

S.S. Eisa
Ain Shams University, Faculty of Agriculture,
Department of Agricultural Botany,
P.O. box 58 Hadayek Shobra, Cairo, Egypt,
e-mail: said_eisa@hotmail.com

M. García Sucre
Director del IVIC (Instituto Venezolano de
Investigaciones Científicas), Caracas, Venezuela,
e-mail: mgs@ivic.ve

B. Herzog
OSTRin i.R Justinus-Kerner-Gymnasium,
74189 Weinsberg, Germany,
e-mail: brigitte.m.herzog@web.de

J. Hoek
Ocean Desert Enterprises,
Amsterdam, The Netherlands,
e-mail: jeannette@oceandesert.nl

H-W. Koyro
Justus-Liebig-University Giessen,
Institute for Plant Ecology, Heinrich-Buff-Ring
26-32, D-35392 Giessen, Germany,
e-mail: hans-werner.koyro@bot2.bio.uni-giessen.de

H. Lieth
Institute of Environmental Systems Research,
University of Osnabrueck, D-49069 Osnabrueck,
Germany,
e-mail: helmut.lieth@t-online.de

F. Pannier and R. Fraino de Pannier
Department of Biology, University of Merida,
Merida, Venezuela,
e-mail: fpannier@hotmail.com

J.E. Paolini
Centro de Ecología, Instituto Venezolano
de Investigaciones Científicas,
Apdo 21827, Caracas 1020-A, Venezuela,
e-mail: jpaolini@ivic.ve

J.P. Rodríguez
Centro de Ecología, Instituto Venezolano
de Investigaciones Científicas,
Apdo 21827, Caracas 1020-A, Venezuela,
e-mail: jonpaul@ivic.ve

A Ruiz Castro
Centro de Ecología,
Instituto Venezolano de Investigaciones Científicas,
Apdo 21827, Caracas 1020-A, Venezuela,
e-mail: augstoruizcastro@yahoo.com

L.E. Sánchez-Arias
Centro de Ecología, Instituto Venezolano de
Investigaciones Científicas, Apdo 21827, Caracas
1020-A, Venezuela, e-mail: luchamangle@gmail.com

V. Sanz D'Angelo
Centro de Ecología Instituto Venezolano de
Investigaciones Científicas, Apdo 21827, Caracas
1020-A Venezuela
e-mail: vsanz@ivic.ve

V. Sardo
Department of Agricultural Engineering, University
of Catania, Via Valdisavoia, 5 – 95123 Catania,
e-mail: sardo@mbox.fagr.unict.it

B.E. Vera Vegas
Centro de Botánica Tropical, Instituto de Biología
Experimental, Universidad Central de Venezuela,
Apdo 47114, Caracas, Venezuela,
e-mail: beatrizesther.veravegas@gmail.com

List of Legends for the Colored Plates

	Page Nr. in the Chapter
Fig. 1.1 Flow chart of work steps for the implementation of saline production systems	4
Fig. 2.1 Already existing halophyte utilisations and utilisation purposes that are under investigation.....	9
Fig. 2.6 Influence of NaCl salinity on the apparent photosynthesis (A), the adaxial transpiration (E), the water use efficiency (WUE) and the stomatal conductance (rs) of <i>Aster tripolium</i> , <i>Beta vulgaris</i> ssp. <i>maritima</i> , <i>Spartina townsendii</i> and <i>Sesuvium portulacastrum</i> . The ultrastructures (SEM-micrograph) of the leaf surfaces (left side controls, right side seawater salinity treatments) are presented next to the responding table	14
Fig. 3.1 On the picture one can see that the <i>Rhizophora</i> is dying on some branches. This is caused by speed boats coming too close to the stiltng roots of these trees at low tide	22
Fig. 3.2 <i>Thalassia</i> stand covered with fine sand which was taken from the bottom which can be seen on the left. Fast going speed boats with tourists disturb the sand and put it over the <i>Thalassia</i>	22
Fig. 3.3 Plastic bottles and other remnants from tourist picnics are found at several places on the mangrove islands in the Morrocoy Park	23
Fig. 5.2 Map: global net primary productivity (NPP), calculated from environmental parameters by Berlekamp et al. taken from http://www.usf.uni-osnabrueck.de/~hlieth	35
Fig. 5.3 Map: terrestrial actual NPP; annual NPP (g dm/m ² /year) of the Actual Vegetation Cover of the World's Land Areas, estimated from NOAA AVHRR Satellite Data (1985–87 average). (Taken from Box E (1993) in Seisan Kenkyu, vol 45 No. 9.)	36
Fig. 5.4 Map: global terrestrial net primary production (NPP) over 110 million square kilometres for 2002, computed from MODIS (Moderate Resolution Imaging Spectroradiometer) data. (Taken from Running et al. (2004) a continuous satellite-derived measure of global terrestrial primary production.)	36
Fig. 5.5 <i>Conocarpus leuocarpus</i> along some UAE highways. (Photo by Lieth H.).....	38
Fig. 5.6 Different mangroves (<i>Laguncularia racemosa</i> , <i>Cocoloba uvivera</i> , <i>Avicennia marina</i>) irrigated with saline groundwater in the sand desert of the UAE near Nashala. Plantation of halophytes (experiment by Lieth A started in 1990) 3 years after the planting. (Photo by Lieth H.)	39
Fig. 5.7 New <i>Avicennia marina</i> plantations on Samaliah Island (UAE). (Photo by Lieth H.).....	39
Fig. 5.8 Greening of parking places with the two species <i>Sesuvium portulacastrum</i> and <i>Conocarpus lanciofolius</i> near Jebel Hafeet/Al Ain (UAE). (Photo by Boer B.)	40

Fig. 5.9	Greenification with <i>Sesuvium portulacastrum</i> and other halophytes on a walk way to Jebel Hafeet. (Photo by Boer B.)	40
Fig. 5.10	<i>Limonium axillare</i> on the beaches of Qatar (Photo by Boer B.)	41
Fig. 5.11	New <i>Avicennia</i> groves along ditches in Qatar. (Photo by Boer B.)	41
Fig. 5.12	Halophyte nursery for landscaping greenification close to the Atlantic near Dakhla (South Morocco). (Photo by Lieth H.)	42
Fig. 5.13	Halophyte nursery behind the Mediterranean coast (Egypt). (Photo by Lieth H.)	42
Fig. 5.14	Hotel greenification with several <i>Atriplex</i> species on the Atlantic beach (Agadir). (Photo by Lieth H.)	43
Fig. 5.15	<i>Cistanche fistulosa</i> (parasite) growing on <i>Atriplex</i> bushes (Agadir). (Photo by Lieth H.)	43
Fig. 5.16	<i>Tamarix</i> sp. and other halophytes growing on an inland Sabkha (Tunisia). (Photo by Mochtschenko M.)	44
Fig. 5.17	Dune fixation with <i>Mesembrianthemum</i> at the coast in Tunisia, demonstrated by Professor Ch. Abdelly. (Photo by KoYRO H-W.)	44
	The photos of the greenification with mangroves at the tourist centre near Pedrogonzales/Isla Margarita were all taken in 2006 by Sanz D'Angelo V. These photos show the present state of the mangroves planted originally by the team headed by Fraino de Pannier R and Pannier F (1988), (see Chapter 11 on page 109)	
Fig. 5.18	General view of the new lagoon with some of the new buildings	45
Fig. 5.19	Mangroves along the hotel bordering the Golf Course	45
Fig. 5.20	Walkway between the mangroves	46
Fig. 5.21	Walkway from the hotel to the Golf Course between the mangroves	46
Fig. 5.22	Lagoon to the hotel complex	47
Fig. 5.23	The connection between the lagoon and the open sea	47
Fig. 5.24a	<i>Rhizophora</i> grove in the centre of the lagoon	48
Fig. 5.24b	Close up of the <i>Rhizophora</i> island in the centre of the lagoon	48
Fig. 6.4	Cover of living mangroves either dominated by <i>R. mangle</i> or <i>A. germinans</i> , deteriorated, and dead mangroves around the gulf of Cuare in (a) year 1972, and (b) year 1998	56
Fig. 6.8	The background shows the mangrove belt, the forest of dead <i>Avicennia germinans</i> in front, the transition zone at the middle and the external fringe with taller trees, chiefly <i>Rhizophora mangle</i> and <i>Laguncularia racemosa</i> , bordering the Caño Pancho tidal creek, Wildlife Refuge of Cuare. Area selected for the samplings of structural parameters and interstitial salinities	58
Fig. 6.9	Dead mangrove <i>A. germinans</i> at the site of Caño Boca del Zorro, Wildlife Refuge of Cuare.	58
Fig. 6.10	Regeneration of <i>A. germinans</i> and <i>R. mangle</i> at the site of Caño Animas, Wildlife Refuge of Cuare. Background dead stems of <i>A. germinans</i>	59
Fig. 6.11	Mixed mangrove forest of <i>Rhizophora mangle</i> and <i>Laguncularia racemosa</i> at Wildlife Refuge of Cuare.	59
Fig. 6.12	Aerial view of mangroves in the sector of Caño de León. The town of Tucácas shows in the background. The inundated zone between the live mangroves corresponds to dead mangroves, presently is a swamp during the rainy season and a saltpan during the dry months	60
Fig. 6.13	Dwarf <i>Rhizophora mangle</i> trees in basin forest at National Park of Morrocoy	60
Fig. 7.2a	Collecting samples	67
Fig. 7.2b	<i>Thalassia</i> and ulvales deposited on shoreline by wave action	67
Fig. 7.3	Dead <i>Thalassia</i> leaves spoil on Adicora beach/Falcón State in the western part of the Venezuelan coast	68
Fig. 7.4	<i>Condriactes gigantea</i> a typical sea-anemone in <i>Thalassia</i> beds from Mochima Bay in the eastern part of Venezuela.	68

Fig. 7.5	Natica egg on <i>Thalassia</i>	68
Fig. 7.6	A cluster of mollusk eggs on the leaf of <i>Thalassia</i>	69
Fig. 7.7	<i>Oreaster reticulatus</i> and <i>Holothuria mexicana</i> in <i>Thalassia</i> beds from Mochima Bay	72
Fig. 7.8	The sponge <i>Irsinia strobilina</i> in a <i>Thalassia</i> bed from Mochima Bay	72
Fig. 9.3	Activation of embryos and hydroponic cultivation, left row above: <i>Rhizophora</i> fruits collected for further treatment, below. <i>Rh.</i> fruits are cleaned, middle row above and middle: preparation of “embryos” for putting them into channels with water, below: bags filled with embryos standing in water for starting to grow, right row from top to bottom: convenient sized stakes are split on one end to fasten the small embryos; the stakes are put into the ground in order to keep the young plants at the water surface	90
Fig. 9.6	View of the degraded area targeted by this study	93
Fig. 9.7	Channels are created to improve flow in the degraded area.....	94
Fig. 10.1 A-C	Climate diagrams relevant for the working zone.....	98
Fig. 10.2A	Aerial view, showing the area of the ancient lagoons which was used to delimit the contours of the area to be dredged.....	101
Fig. 10.2B	Map of Isla Margarita showing the geographical position of the new mangroves southeast of the Golf Course and the Hotel Hesperia near the township of Pedro Gonzalez, (source: Parks Watch 2003)	101
Fig. 10.5	View of the open greenhouse with the tanks used for acclimatization of the mangrove plants	104
Fig. 10.6	View of a tank sector containing the potted plants.....	104
Fig. 10.7	Transporting the plants to the planting sites	104
Fig. 10.8	Planting inside a micropond	105
Fig. 10.9	View of microponds after planting	105
Fig. 10.10	The picture shows the dense stands on both sides of the lagoon behind the hotel (photo 2006).....	106
Fig. 10.11	The figure shows the dense stands of a mangrove mixed <i>Rhizophora</i> , <i>Laguncularia</i> and <i>Conocarpus</i> between the walkway and the lagoon (photo 2006).....	106
Fig. 11.2	Infrared photography of one of the islands showing the position of the various vegetation types.....	111
Fig. 12.1	Small plastic growth chambers in 2,600 m elevation. Villapinzón near the tannery: V 1 (nursery 2) partially covered with plastics against rain and UV, V 2 (nursery 1) totally covered	121
Fig. 12.2	View of the plastic growth chamber at Villapinzón.....	122
Fig. 12.3	Interior of the warmer chamber filled to about 50 cm height with tannery wastewater into which the young mangroves were placed	122
Fig. 12.4	Young plants of <i>A. germinans</i> (in front) and <i>Rh. mangle</i> (behind) in the warmer growth chamber during the experiment	123
Fig. 12.5	Young plants of <i>Rh. mangle</i> (front section) and <i>A. germinans</i> (behind) in the warmer growth chamber during the experiment	124
Fig. 12.6	Climate diagram Bogota/Eldorado/Colombia.....	124
Fig. 12.7	Climate diagram Chinchina/Colombia	125
Fig. 14.1	Don Antonio from the Ejido Luis Encinas Johnson walks through the new pilot plantation of woody halophytes irrigated with saline groundwater	149
Fig. 14.2	View of a piece of wasteland in the Colorado River delta region proposed for the enlarged scale of the 30 ha pilot plantation described in this paper (to a business type pilot forest for industrial usage of 5000–10000 ha in size)	150
Fig. 14.3	Before planting becomes the area a drainage system and will be irrigated with saline groundwater.....	150
Fig. 14.4	Preparing the field for high-density planting, growing <i>Tamarix aphylla</i> , cutting in ditches for effective irrigation with saline groundwater	151

-
- Fig. 14.5** *Tamarix aphylla* plantation in a three ha plot 5 months after plantation and irrigated with saline groundwater 151
- Fig. 14.6** High-density plantation of *Tamarix aphylla* about one year after the planting 152
- Fig. 14.7** In a few years grows *Tamarix aphylla* into trees with several stems, which can be used to cut new propagules to replace the harvested trees from the proposed 5,000 ha trial plantation to study the use of the poles for industrial purposes 152

List of Tables

Table 1.1	Utilisation of halophytes already existing and possibilities under investigation. (According to Lieth and Mochtchenko 2002).....	4
Table 4.1	Summary of results obtained irrigating with variously diluted seawater.....	26
Table 4.2	Dry matter production (grams/plant) in different <i>Atriplex</i> accessions as affected by water salinity – same letters in rows indicate no significant differences at 5% probability (Tukey HSD test).....	28
Table 4.3	Ash content of <i>Vetifer</i> grass vs. salinity.....	29
Table 5.1	Sequenced organisms. (Taken from von Homeyer A 2003).....	34
Table 6.1	Annual variations of rainfall and length of the dry season in the National Park of Morrocoy and Wildlife Refuge of Cuare.....	53
Table 7.1	Common faunal groups on the beds of <i>Thalassia testudinum</i> in the northwestern regions of Venezuela.....	70
Table 8.1	Physicochemical parameters, enzyme activities and microbial biomass carbon for the analysed soils.....	82
Table 9.1	Concentration of salts and metals and total plant development, 6 years after planting (ICP 2000).....	87
Table 9.2	Properties of water at different locations within the experimental area (ICP 2000).....	88
Table 9.3	Water quality of the natural water source (“natural”), inside the artificial wetland (“collector”), and after it leaves the facility (“exit”) in terms of total suspended solids and biological oxygen demand (mg/l). p_1 and p_2 are one-tailed t-tests probabilities, comparing the mean for natural vs. exit and collector vs. exit, respectively.....	90
Table 9.4	Relative size and abundance of fish species captured in the wetland.....	90
Table 10.1	Plant species listed on the surface of the sedimented lagoon system before its dredging. Total area surveyed: 14.500 m ²	100
Table 10.2	Final distribution of the plants.....	107
Table 11.1	Comparison of soil characters in three sampling sites (A, B, C) indicated in transect 2 (see Fig. 11.4).....	115
Table 12.1	Factorial design used.....	121
Table 12.2	Summary of monthly environmental temperatures (median, minimum and coldest) and average monthly nursery temperatures during the period of monitoring.....	125

Table 12.3	Number of leaves developed over time by <i>Rhizophora mangle</i> growing in tannery water in warm and cold environments	127
Table 12.4	Number of leaves developed over time by <i>Avicennia germinans</i> growing in tannery water in warm and cold environment.....	127
Table 12.5a	Water analysis from the Villapinzón Tannery	127
Table 12.5b	Mineral content of wastewater from the Toldado oil field development	127
Table 13.1	Fresh weight (fw), water content, dry matter (dm) and ashweight (aw) of quinoa seeds grown at 0, 100, 200, 300, 400 and 500 mol m ⁻³ NaCl salinity (0%, 20%, 40%, 60%, 80% and 100% seawater salinity respectively)	138
Table 13.2	Nitrogen (N), carbon (C), sulphur (S), protein and carbohydrate content of quinoa seeds grown at 0, 100, 200, 300, 400 and 500 mol m ⁻³ NaCl salinity (0%, 20%, 40%, 60%, 80% and 100% seawater salinity respectively)	138

Color Plates

Several attendees used during the seminars some colored photos and figures. In the text of the 14 chapters we could use black and white copies only. Dr. Garcia Sucre allowed us therefore to add a selection of this special colored plate section. In this section we included pictures for which we assumed that the color improves significantly their value.

These figures belong to different papers. We kept for each figure the same figure Nr. and figure legend for both locations, in the chapters as well in the colored plates. In the figure Nr. refer the front digits before the decimal point to the chapter and the digits after the decimal point to the figure Nr. in the chapter. These figures appear in the colored plate section with Roman page Nr. and in the text of the chapters with Arabic page Nr. as shown in the table of contents and in the list of figures.

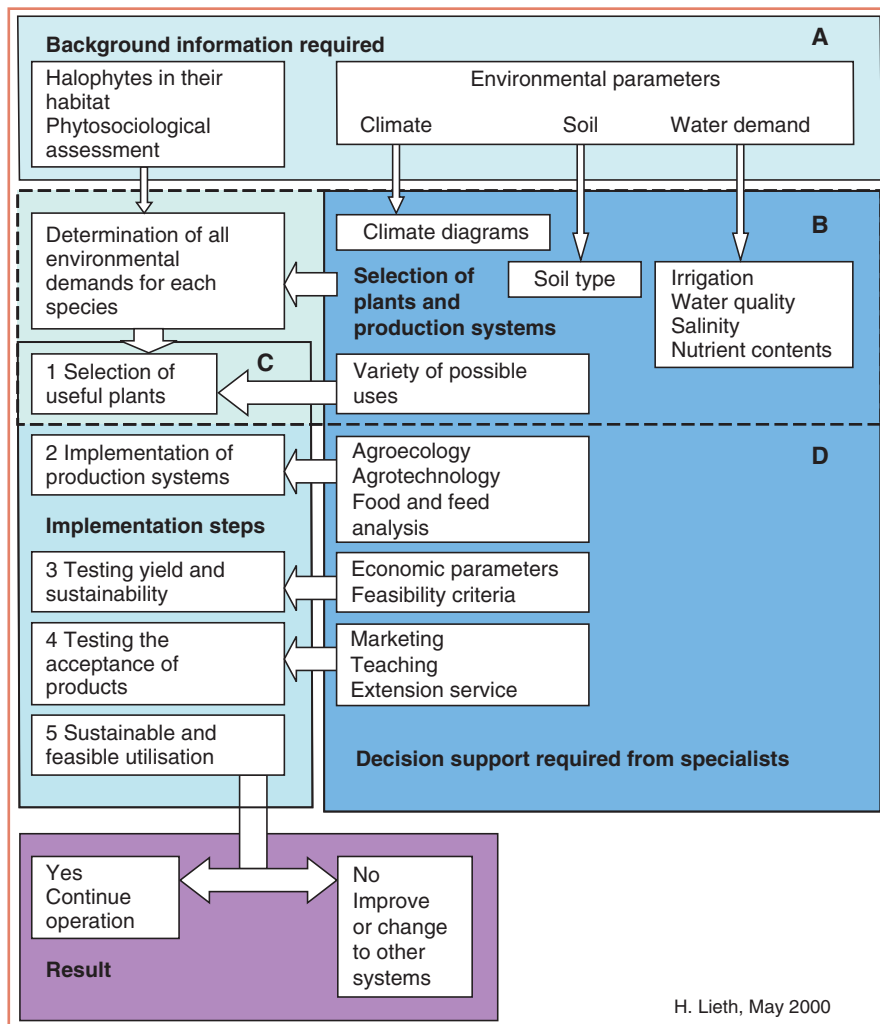


Fig. 1.1 Flow chart of work steps for the implementation of saline production systems (See p. 4)

Possibilities for halophyte utilisation

Table 1: Utilisations of halophytes for already existing and utilisation purposes that are under investigation.









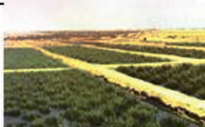


1 Food Starch Protein Fat Vitamines		2 Feed Starch Protein Minerals		3 Wood Fire Building Crates		4 Chemicals Industrial chemicals Pharmaceuticals Plastics	
5 Landscaping Roadside Housing areas Dune fixations		6 Ornamental Potting plants Gardening		7 CO₂-sequestration Greenification Aforestation		8 Tertiary treatment Water Soil	 
9 Industrial raw material Fiber Biomass Biofuel		10 Unconventional irrigation water		11 Environmental protection Coastlines Turf		12 Wildlife support Species diversity	

Fig. 2.1 Already existing halophyte utilisations and utilisation purposes that are under investigation (See p. 9)

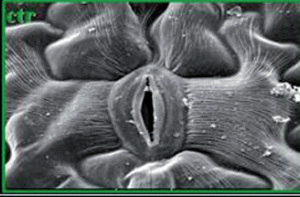
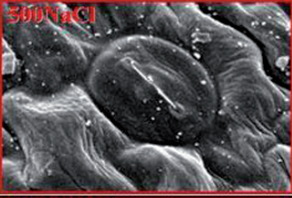
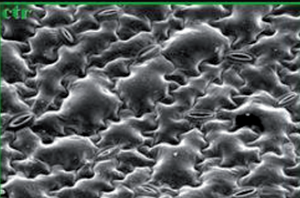
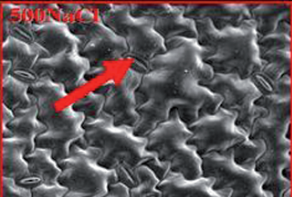
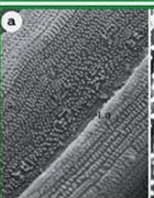
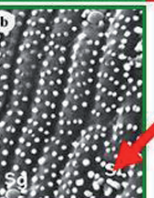
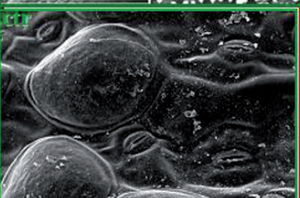
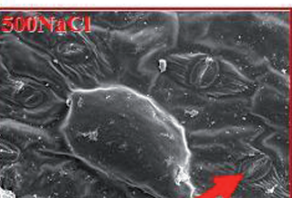
<i>Aster tripolium</i>	A ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	E ($\text{mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	WUE (A/E)	rs ($\text{m}^2 \cdot \text{s} \cdot \text{mol}^{-1}$)		
control	24.30 +3.14	3.81 +0.37	6.58 +1.25	3.21 +0.29		
125NaCl	17.20 +3.69	3.89 +0.58	4.38 +0.35	5.29 +0.55		
375NaCl	7.88 +2.22	2.10 +0.63	3.76 +0.50	42.33 +2.55		
500NaCl	4.26 +0.66	1.22 +0.47	3.49 +1.88	156.74 +13.64		
<i>Beta vulgaris ssp. maritima</i>	A ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	E ($\text{mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	WUE (A/E)	rs ($\text{m}^2 \cdot \text{s} \cdot \text{mol}^{-1}$)		
control	2.79 +0.22	1.82 +1.30	1.53 +0.69	6.44 +2.90		
125NaCl	3.13 +0.20	1.87 +0.64	1.68 +0.56	4.53 +1.24		
375NaCl	2.90 +0.10	1.17 +0.11	2.47 +0.17	9.67 +1.23		
500NaCl	1.58 +1.01	0.44 +0.27	3.62 +2.44	31.45 +16.73		
<i>Spartina townsendii</i>	A ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	E ($\text{mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	WUE (A/E)	rs ($\text{m}^2 \cdot \text{s} \cdot \text{mol}^{-1}$)		
control	6.25 ±1.04	3.30 ±0.20	1.90 ±0.45	0.82 ±0.20		
125NaCl	8.17 ±1.01	3.17 ±0.34	2.57 ±2.34	1.46 ±0.59		
250NaCl	7.48 ±2.52	2.68 ±0.21	2.79 ±1.22	1.72 ±0.32		
375NaCl	7.25 ±2.26	2.29 ±0.20	3.17 ±1.31	2.49 ±0.74		
500NaCl	7.52 ±1.54	1.25 ±0.26	6.01 ±1.92	5.06 ±1.99		
<i>Sesuvium portulacastrum</i>	A ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	E ($\text{mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	WUE (A/E)	rs ($\text{m}^2 \cdot \text{s} \cdot \text{mol}^{-1}$)		
control	5.47 +1.06	1.46 +0.20	3.76 +0.22	28.45 +4.88		
125NaCl	6.53 +0.25	1.67 +0.34	3.90 +0.34	26.40 +4.28		
375NaCl	6.95 +0.57	1.42 +0.02	4.87 +0.50	24.36 +0.28		
500NaCl	7.44 +0.81	1.51 +0.26	4.98 +0.36	22.60 +2.32		

Fig. 2.6 Influence of NaCl salinity on the apparent photosynthesis (A), the adaxial transpiration (E), the water use efficiency (WUE) and the stomatal conductance (rs) of *Aster tripolium*, *Beta vulgaris ssp. maritima*, *Spartina townsendii* and *Sesuvium portulacastrum*. The ultrastructures (SEM-micrograph) of the leaf surfaces (left side controls, right side seawater salinity treatments) are presented next to the responding table (See p. 14)



Fig. 3.1 On the picture one can see that the *Rhizophora* is dying on some branches. This is caused by speed boats coming too close to the stilted roots of these trees at low tide (See p. 22)



Fig. 3.2 *Thalassia* stand covered with fine sand which was taken from the bottom which can be seen on the left. Fast going speed boats with tourists disturb the sand and put it over the *Thalassia* (See p. 22)