RECLAMATIVE PRODUCTION MODELS ANALYSIS AS AN INTEGRAL PART OF AMELIORATION OF MULTY LAYER SOILS

UPORODNA ANALIZA MODELA REKLAMATIVNE PROIZVODNJE KAO INTEGRALNOG DELA MELIORACIJA VIŠESLOJNIH ZEMLJIŠTA

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SUMMARY

Land Reclamation process has been realized upon a two fundamental stages within 24 months period: Initial salt leaching and Initial salt leaching during the reclamative production.

The subjective examinations, applied methods-models and obtained results, represents the integral part of the complete experimental investigations of Land Reclamation of saline soils. (founded, 1985, 2001. and 2007 and 2013/2014.).

Reclamative production ought to be designed at the areas where obtained soil salt content is < 4 mmhos/cm.

The fundamental tasks of the reclamative production are: Increasing the soil desalinization efficiency, achieving of the adequate level of soil fertility, humification of the AH layer, improvement of soil water properties and structure, reestablishing of microbiological activity. The selection of the reclamative production optimal model has been based on: a. Crop rotation model analyses and selections, b. Analyses of land cultivation technology varieties, c. Reclamative production irrigation methods and practices application.

After the II stage of land reclamation completion, all soil classes at the treated area might be included in the regular, stable production where all crop varieties could be cultivated, i.e. that the fundamental task of the Land Reclamation process has been attained.

Key words: Reclamative production, desalinization, consumptive use, initial salt leaching, crop rotation.

1. INTRODUCTION

The problem of desalinization of highly saline soils has drawn significant attention of researchers, not only in past, but at present time, too. However, having in mind the wide area of s.c. “unproductive” lands, it is obvious that only the minor part has been reclaimed.

The majority of scientific researches have been realized within the territory of Republic of Iraq (South-East Mesopotamia), where the most of the investigations has been
organized. The common for all was, to investigate the possibility of soil salt leaching, to define the conditions and effects of certain crops cultivation, so after the hard desalinization procedure to re-establish “regular” agriculture production.

Besides Iraqis, Dutch, Russian and American, a research activities have been dominantly established by the Serbs.

Based on the world literature dates, it is noted that the first soil desalinization experiment in Iraq has been organized by Strachan at the area of Saklawizah during the Yr.1927-1929. The experiment was based on the idea of periodical salt leaching test during the crop cultivation (Rise, Wheat and Barley).

During the 1954-1955 and than twice up to 1975., the Dutch founded experimental fields in Dujailah Region at highly saline soils. The complete field infrastructure, included field-pipe drainage, irrigation system with hydrants, has been properly provided. The obtained results have indicated that the applied leaching rate of 35 cm, has reduced soil salt content up to 60 cm, for 10%. During the reclamative period, the following crops have been cultivated: Wheat, Barley, Alfa-alfa, Bersim, Sweet clover, Potato. Sweet clover shown salt resistance rated 8 mmhos/cm in relation to Alfa-alfa. Both variants of Sweet clover (Melilotus albus and officinalis), have displayed as convenient crops for reclamative production. The Bersim as the crop resistant to high soil salt content, gained vary low yield.

Halomorphic soils of Serbia, the same as the equivalent once in the world, engrossed the significant vigilance of Serbian science. Part of examinations has escorted in field of chemical amelioration by gypsum and lime and their influence to chemical characteristics of “Slatine”. The objective of the investigations was concerned to applied land reclamation measures related to cultivation of different crop varieties.

The basic concept of Reclamation of agriculture lands is defined by the natural conditions of the region, as well as the rapid agriculture production development aiming the achievement of the first yield, were crop production has been unstable or insignificant

In sense of the above mentioned concept, Land Reclamation process is been realized upon two fundamental stages within two years period:

- Initial salt leaching up to the level which provides conceived agriculture production.
- Initial salt leaching during the reclamative production.

Following 2 year Land Reclamation period the physical-chemical and biological soil properties are considerable improved, providing their transfer toward the “Normal Soils”, were cultivation of sustainable agriculture production may take place.

The subjective examination, obtained and presented results referred to applied models of reclamative production, represents the integral part of the complete experimental investigations of Land Reclamation of highly saline soils, done by the author1 up to 2007.

It’s of the great importance to emphasize that the reclamative production ought to be designed within the areas where the process of initial salt leaching is been completed, i.e. soil salt content is <4 mmhos/cm.

The main tasks of the reclamative production are the following:

- Increasing the soil desalinization efficiency.
Achievement of the adequate level of soil fertility by NPK and micro elements treatments.

- Humification of the AH layer by organic green mass ploughing.
- Improvement of soil water properties and structure by herbs and legumes cultivation, using adequate and specific land cultivation technology-“Mechanical Reclamation”.
- Re-establishing of microbiological activities by soil bio-chemical process activation.

The selection of the reclamative production optimal model has been realized in accordance to:

a. Crop rotation models analyses and selection.
b. Analyses of land cultivation technology varieties
c. Reclamative production irrigation methods and practices applications.

The obtained results of analysis have been incorporated into the basic concept of desalinization of highly saline anizotrophical soils.

2. MATERIALS AND METHODS

Setting of II stage of Land Reclamation models investigations are denoted as reclamative-temporary production, realized at the same experimental plots where initial salt leaching process has been finalized in continuation, depending on the achieved soil salinity level. 3 experimental plots, representing different textural, physical-chemical soil properties including initial salt content, have been selected. The chosen experimental fields were 20 ha area, 60 ha total (Žeželj, 2013).

Taking water from Main Dujailah cannel, trought earth and than secondary canals, regulated by the gates, irrigation water is released in distributaries. At the distributaries, executed laterally to plots (in length of 1000 m), hydrants outlets, spacing 60 m have been placed. Complete infrastructure, including field-pipe drainage at the depth of 2, 2 m and spacing of 65 an 75 m has been installed too.

Prior to optimal reclamative models selection, the following analyses and examinations took place:

2.1. Optimal crop rotation model Analyses and Selection.
2.2. Reclamative crops production cultivation technology variants analyses.
2.3. Reclamative production irrigation methods selections and evaluations.

2.1. Optimal crop rotation model Analyses and Selection

The reclamative production basic criterions selection are nominated and presented herewith (Dieleman, 1973; Žeželj, 2013):

a. Soil salinity degree (soil salinity class).
b. Level of crop salinity tolerance.
c. Crops ameliorative worthy.
d. Crop water requirements-consumptive use.
e. Reclamative crops economical value.

Taking into consideration the above mentioned criterions, as well as the actual-designed agriculture production requirements for given natural, climate and soil conditions, the following reclamative crops have been selected:
• Bersim, Alfa-alfa, Winter mixture, Summer mixture, Barley, Sweet clover, Suddan grass.

Only the crops which fulfil the above criterions in complete, will be chosen as the “reclamative crop production stretchers “and might take part in “sustainable crop rotation model defining” (Gracanin, 1964).

All of 3 particular experimental plots, are separated in accordance to reclamative crops into 8 production units, 2, 5 ha area each.

In the first year of the reclative production all the selected crops have been sown in accordance to the designed sowing calendar (winter-summer season).

At the end of the first vegetation season, after the elimination of the crops whish haven’t fulfilled the anticipated criterions, the final selection of the crops convenient for growing upon different soil salinity conditions, took part in forming the optimal crop rotation models.

At the end of the first winter and the first summer vegetation season, it was strengthened that the following crops were not fulfilled defined conditions and criterions, and consequently couldn’t reach second year of reclamative production: Bersim, Horse-been, Alfa-Alfa, winter and summer mixture.

Calendar and crop rotation model
In this study, beside listed conditions, growing crop calendar is defined and based on the following principles (Molnar, at al., 1989):
• Biological characteristics of the crops.
• Specific importance and place of certain crop in Land Reclamation process.
• Rational consumption of available water, both, for irrigation and desalinization too.

For crop rotation determination, the method of two years reclamation period continual cycle, based on growing structure and soil salinity class have been applied. On the other side, time and schedule of reclamative production implementation has been defined by different crop rotation models, such as:

**Model A** (soil salinity class I, ECo<20 mmhos/cm) -This crop rotation model is applied on the area where initial soil salt content is less than 20 mmhos/cm. After the completion of initial salt leaching, lasting 15 days, Land Reclamation process will continue over the reclamative production, in accordance to the principle given in table 1.

<table>
<thead>
<tr>
<th>Crop Production Year</th>
<th>Winter (October-May)</th>
<th>Summer: (April-September)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Barley</td>
<td>Fallow</td>
</tr>
<tr>
<td>2</td>
<td>Sweet clover</td>
<td>Fallow</td>
</tr>
<tr>
<td>3</td>
<td>Regular Crop production</td>
<td></td>
</tr>
</tbody>
</table>

During the first winter season after the initial salt leaching, entire land area ought to be covered by Barley. When second winter season commence, Barley will be replaced by Sweet clover. This crop rotation model excludes production during the summer season. Moreover, the whole area will be placed under the fallow. During the fallow period, Barley stubble will be plough in. During the second year Sweet clover green mass will be
plough into the soil too. After that, complete area will be transferred into the Regular production.

**Model B** (soil salinity class II, ECo >20<40 mmhos/cm)-This crop rotation model is applied on the area where initial soil salt content is between 20-40 mmhos/cm in accordance to the scheme given in table 2.

<table>
<thead>
<tr>
<th>Crop Production Year</th>
<th>Growing season during the year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter (October-May)</td>
</tr>
<tr>
<td>1</td>
<td>Sweet clover</td>
</tr>
<tr>
<td>2</td>
<td>Barley</td>
</tr>
<tr>
<td>3</td>
<td>Regular Crop Production</td>
</tr>
</tbody>
</table>

Table 2. Model B (Soil Salinity Class II, Eco >20<40 mmhos/cm)

This crop rotation model includes initial soil salt leaching lasting 4 months. The reclamative production has organized at the end of the first season by sowing of Sweet clover during the three months vegetation period.

At the beginning of the summer season, (first year of rotation), the entire cultivated area under the Sweet clover has ploughed, due to organic matter provision. During the summer period the whole area has been placed under the fallow.

During the second winter season, whole area has sown by crop of Barley. After the harvesting of Barley and stubble plough in, the land has converted to the fallow. Within the second summer season, the area has been optionally transferred to fallow, or has sown by Sudan grass, depending on the availability of water required for additional salt leaching. At the end of the summer period Sudan grass has ploughed in, due to soil humification process activation. Next autumn the complete land area will be included into the Regular production.

**Model C** (soil salinity class III, ECo > 40 mmhos/cm) - This crop rotation model is applied to the soils with the highest soil salt content, i.e. > 40 mmhos/cm in accordance to the scheme given by table 3.

<table>
<thead>
<tr>
<th>Crop Production Year</th>
<th>Growing season during the year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter (October-May)</td>
</tr>
<tr>
<td>1</td>
<td>Barley</td>
</tr>
<tr>
<td>2</td>
<td>Sweet clover</td>
</tr>
<tr>
<td>3</td>
<td>Regular Crop Production</td>
</tr>
</tbody>
</table>

Table 3. Model C (Soil Salinity Class III, Eco > 40 mmhos/cm)

This crop rotation model includes initial soil salt leaching with the maximal duration of 5-6 months.

After the soil salt leaching process completion, realized during the entire first winter season, complete land area has cultivated and sown by Sweet clover. Vegetation of this crop has prolonged during the summer period of the second year. Second Sweet clover harvest has ploughed in and than the area has prepared for second winter season and sowing of Barley.
During the second summer season, the complete area is cultivated and covered by Sudan grass to be ploughed during the autumn in order to provide organic matter. After that organization of regular production will take place (Aboukhaled, 1972).

2.2. Reclamative crops production cultivation technology variants analyses.

During the Land Reclamation treatment, two land preparation stages with different working operations have been designed.

I Stage-land preparation, prior to initial salt leaching, including: Sub soiling, 40-60 cm depth, ploughing up to 15 cm, two direction disc harrowing, fine levelling, preparation of filed irrigation infrastructures.

II Stage-land preparation for reclamative crop production. In relation to crop type, salinity class, soil texture and stratigraphy, different soil preparation models have been applied (Taylor, 1982). The following variants have been analyzed:

- Dismantling and planning of embankments and ditches backfilling.
- Both, variant with and without land levelling.
- Primary ploughing at 4 depts variants: 15cm, 20cm, 25cm and 30 cm.
- Soil preparation for sowing.
- Both variants, with and without disc harrowing.
- Both variants, with and without fine land levelling.
- Construction of basin, border-strip and sprinkler irrigation infrastructures.

2.3. Reclamative production irrigation methods selections and evaluations

After the initial salt leaching process completion and sowing of reclamative crops in accordance to the designed crop pattern, the vegetative irrigation took place. In addition to the irrigation rate required for regular crop growth, the “planned leaching waster quantities” has been designed. The basic function of these water quantities is the maintenance of attained soil salt balance at the depth of 60 to 80 cm, less than 4 mmhos/cm and at the same time the continuation of soil desalinization during the reclamative crop production (Dieleman, 1973. Žeželj, 2013).

During the period of initial salt leaching the water is released into the cassettes-basins, while during the reclamative production crop vegetation water distribution has been executed in accordance to the irrigation methods applied, upon the influence of:

- Land configuration, general land slope direction hydrant-collector drain and crop type.

The following irrigation methods have been used and analyzed:

a. Surface irrigation methods: Border strip (overflowing) and cassettes- basins (flooding).


For monthly reclamative crops water requirements estimation, the Blaney-Criddle method as competitive for the South-East Mesopotamian valley has been used (Blaney, Criddle, 1950., 1962).

In table 1, the review of consumptive use results for Barley, Sweet clover and Sudan grass is presented, while the EC-evapo-transpiration values by the table 2.
Field irrigation schedule is based on the water balance, expressed by the water duty value and intervals between each irrigation application rates. Just to remain, that the irrigation application rate is the depth of water held in the roots zone between field water capacity and wilting point, depending on crop type, soil properties, climatic and natural conditions.

Estimation of net irrigation rates is carried out for clay-loam and loamy soils, representing dominant soil texture classes, using the following equation:

\[ d = 100 \times D \times (F.C. - W.P.) \times 0.70, \]

where

- \( d \) - net irrigation rate (m\(^3\)/ha),
- \( D \) - depth of soil layer to be irrigated,
- \( F.C. \) - field capacity (m\(^3\)/\%)
- \( W.P. \) - wilting point (m\(^3\)/\%).

Estimated monthly crop consumptive use values are enlarged by the so call “additional-planned leaching rate”, equal to 60 mm water depth, each month during the reclamative crop production vegetation. This quantity is in function of pipe drainage hydro modulo of \( q=2 \) mm/day (Beltron, 1978).

Table 3. Consumptive use in mm, by Blaney-Criddle

<table>
<thead>
<tr>
<th>Crop</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>20</td>
<td>43</td>
<td>63</td>
<td>84</td>
<td>108</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>344</td>
</tr>
<tr>
<td>Sweet clover</td>
<td>159</td>
<td>82</td>
<td>49</td>
<td>59</td>
<td>100</td>
<td>162</td>
<td>268</td>
<td>336</td>
<td>356</td>
<td>333</td>
<td>245</td>
<td></td>
<td>1.860</td>
</tr>
<tr>
<td>Sudan grass</td>
<td>137</td>
<td>227</td>
<td>315</td>
<td>350</td>
<td>268</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.297</td>
</tr>
</tbody>
</table>

Table 4. Average monthly ET value estimation (example for Sudan grass)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Temperature (°C)</th>
<th>Insolation</th>
<th>ET factor</th>
<th>Climatic Coeff.</th>
<th>Crop grow Coeff.</th>
<th>ET Coeff.</th>
<th>ET Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>29,2</td>
<td>9,62</td>
<td>6,36</td>
<td>1,23</td>
<td>0,9</td>
<td>0,85</td>
<td>137</td>
</tr>
<tr>
<td>May</td>
<td>33,3</td>
<td>9,60</td>
<td>8,13</td>
<td>1,28</td>
<td>0,9</td>
<td>1,10</td>
<td>315</td>
</tr>
<tr>
<td>June</td>
<td>35,1</td>
<td>9,77</td>
<td>8,87</td>
<td>1,34</td>
<td>1,0</td>
<td>1,40</td>
<td>315</td>
</tr>
<tr>
<td>July</td>
<td>31,7</td>
<td>9,28</td>
<td>9,33</td>
<td>1,33</td>
<td>1,1</td>
<td>1,47</td>
<td>350</td>
</tr>
<tr>
<td>August</td>
<td>25,8</td>
<td>8,34</td>
<td>8,81</td>
<td>1,23</td>
<td>0,9</td>
<td>1,20</td>
<td>268</td>
</tr>
<tr>
<td>Total Season</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.297</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Reclamative crop production analyses and optimal models selection have been realized at the experimental fields of 60 ha area (20 ha each plot). Prior to the mentioned analyses, the measuring, notification and escorton of the suggested models emphasising the II desalinization stage-Reclamative crop production, are presented and discuses herewith:
1. Out of 8 chosen crops (Bersim, Horse-been, Alfa-alpha, Winter and Summer mixture, Barley, Sweet clover and Sudan grass), after the first year of the reclamative production, it was stated that the first five haven’t fulfilled the given criterions:
   a. The reversible process, so called “secondary salinization”, took place, increasing the obtained salt content from 4 up to 7-8 mmhos/cm.
   b. Green mass treated with NPK fertilizer haven’t proved expected results when organic matter is concerned. Moreover, the selection criteria of crops ameliorative worth are not proved.
   c. Besides, the essential reason of the mentioned deviation corresponding with the water quantities applied during the vegetation as well as “additional leaching requirements” ranging 60 mm/month.
   d. At the 1/3 of the experimental plots areas, belonging to clay-loam, the mineralized ground water rising, gathered the soil desalinization process.
   e. Reclamative crops economical value criterion hasn’t achieved too.

2. The crops fulfilled the specified and required criterion are Barley, Sweet clover and Sudan grass, participated in designing all of 3 basic crop rotation models.
   The analyses confirmed that the Barley included in early desalinization stage, as shallow root system and high salt tolerance crop, beside significant ameliorative worth, gives pretty high economical volubility, by reducing the production fees. In same time, the Barley provides rapid livestock production introduction.
   Sweet clover is marked as the main reclamative crop, distinguished by the deep, robust and developed root system. Intensive and developed surface and underground vegetative mass use to provide organic matter of the cultivated layers. Depending on the rotation model, the Sweet clover can be sown as the winter as well as summer season culture.
   Sudan grass is been cultivated specifically as a summer season crop, for autumn green mass plough in. This culture gives rather high reclamative effects due to huge sub surface vegetative mass as well as by deep root system. She’s moderately tolerant to soil salt concentration. Participation of Sudan grass in crop pattern is equal to Barley.
   All adopted crop rotation models are designed for two years period. After the expiration of this period, all soil classes will be brought at the same physical, chemical and biological characteristics. By this, the conditions for regular-planned and sustainable agriculture production will be ensured.

3. Within the II land preparation stage for reclative production, the following working operations have been evaluated and finally accepted: Dismantling the embankments and canals backfilling, land levelling, ploughing 25-30 cm, land preparation for sowing, fine levelling, and construction of basin, border-strip and inside sprinkler irrigation infrastructures.
   Reclamative production technology includes also an adequate crop care, protection and fertilization systems, taking into consideration a specific soil condition as well as biological and genethical figures of selected crop types.

4. Desalinization process continuity during the reclamative production imperatively depends on accepted and applied irrigation methods in relation to soil texture and structure, as well as chosen crop kind.
The results given in table 2, represents the average monthly ET values for Sudan grass, as the dominant summer season crop. The highest ET value have noted in months of July (350 mm) and June (315 mm), while the lowest one in April (137 mm). These values indicate in the same period the peak consumptive use of the reclamative production crops of 350 mm, during the August. Consequently the irrigation intervals are minimal, i.e.3-4 days. The lower consumption for Barley is in November (26 mm) and highest in April (108 mm). Minimal consumption for Sweet clover is in January (47 mm) and maximal in July (356 mm).

The “additional leaching water requirement” is equal to field drainage hydro module of 2 mm/day or 60 mm monthly, to be applied each month during the reclamative production.

5. The analysis comprised 3 irrigation methods, 2 conventional and 1 hi-tech., such as:

- Border strip irrigation (overflowing).
- Basin-shassettes irrigation (flooding).
- Sprinkler irrigation by means of self driving automatic equipment in combination with top-guns and rain ramps (booms).

It is confirmed that the best effects on soil and crops during the reclamative production are realized by border strip irrigation methods. During the regular crop production the priority will be given to hi-tech.irrigation methods, including “micro irrigation” (drip irrigation and micro-jets). Basin irrigation is not suggested for the selected crops of reclamative production.

4. CONCLUSIONS

1. Land Reclamation process has been realized upon two fundamental stages within 2 years period: Initial salt leaching and Initial salt leaching during the reclamative production.

2. The reclamative production ought to be designed within the areas where the initial salt content is <4 mmhos/cm.

3. The selection of the reclamative production optimal model has been realized in accordance to: Crop rotation models selection, analyses of land cultivation technology variants and irrigation methods and practices to be applied.

4. For crop rotation determination, the method of two years reclamation period continual cycle, based on growing structure and soil salinity class have been applied.

5. The optimal technological procedures and land preparation measures as well as crop care and protection and fertilization system have been implemented.

6. The analysis comprised 3 irrigation methods, 2 conventional and 1 hi-tech. It was confirmed that the best effects on soil and crops have been achieved by the border strip irrigation methods application.

7. After the II stage of land reclamation completion, all soil classes at the treated area might be included in the regular, stable production where all crop varieties could be cultivated.
5. LITERATURE


UPOREĐENA ANALIZA MODELA REKLAMATIVNE PROIZVODNJE KAO INTEGRALNOG DELA MELIORACIJA VIŠESLOJNIH ZEMLJIŠTA

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REZIME
Kompleksne melioracije zemljiša su sprovedene u okviru dve fundamantalne faze, u toku dvogodišnjeg perioda: Inicijalno ispiranje soli i ispiranje soli iz zemljišta u toku prelazne-reklamativne proizvodnje.

Predmetna istraživanja, primenjeni metodi-modeli, te ostvareni rezultati predstavljaju integralni deo kompletnih eksperimentalnih istraživanja kompleksnih melioracija zasoljenih zemljišta (ostvarenih 1985, 2001 i 2007 god.). Prelaznu-reklamativnu proizvodnju treba planirati na svim onim površinama na kojima je postignut stepen saliniteta < 4 mmhos/cm.

Fundamentalni zadaci reklamativne proizvodnje su: Povećanje efikasnosti desalinizacije zemljišta, postizanje adekvatnog nivoa zemljišne plodnosti, humifikacije AC horizonta zaoravanjem zelene organske mase, poboljšanje vodno-fizičkih osobina i strukture zemljišta, uspostavljanje mikrobiološke aktivnosti sredine.

Izbor optimalnog modela prelazne-reklamativne proizvodnje izvršen je na osnovu:

a. Analiza i izbor optimalnog modela rotacije useva.
b. Analiza varijanti tehnologije gajenja useva reklamativne proizvodnje.
c. Vrste i metodi navodnjavanja useva reklamativne proizvodnje.

Po realizaciji II faze reklamacije zemljišta, sve zemljišne klase na tretiranoj površini mogu se uvesti u redovnu, stabilnu proizvodnju, u okviru kojih se mogu gajiti sve biljne vrste, što je ostvaren fundamentalni zadatak kompleksnih melioracija-desalinizacija zaslanjenih zemljišta.

Ključne reči: Reklamativna proizvodnja, desalinizacija, potrošnja vode, inicijalno ispiranje soli, rotacija useva.