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**ANALYSIS OF DIFFERENT RECLAMATION PRODUCTION MODELS, A
BASIC CONDITION FOR LAND RECLAMATION OF SALINE SOILS
ANALIZA PRIMENE DIFERENTNIH MODELA PRELAZNE-REKLAMATIVNE
PROIZVODNJE, USLOV KOMPLESNIH MELIORACIJA ZASOLJENIH
ZEMLJIŠTA**

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SUMMARY

Land Reclamation process was realized upon two fundamental stages within a 2-year-period: Initial salt leaching and Initial salt leaching during the reclamation production.

The subjective examinations, applied methods-models and obtained results represent the integral part of the complete experimental investigations of Land Reclamation of saline soils (realized in 1985, 2001 and 2007).

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

The fundamental tasks of reclamation production are: Increasing the soil desalinization efficiency, achieving the adequate level of soil fertility, humidification of the AH layer, improvement of soil water properties and structure, reestablishing of microbiological activity. The selection of the reclamation production optimal model is based on: a. Crop rotation model analyses and selections, b. Analysis of land cultivation technology varieties, c. Kinds and methods of crop irrigation in reclamation production. After the completion of stage II of land reclamation, all soil classes in the treated area might be included in the regular, stable production where all crop varieties could be cultivated, i.e. the fundamental task of the Land Reclamation Process is attained.

Key words: reclamation 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 the past, but in the 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 research was realized within the territory of Republic of Iraq (South-East Mesopotamia), where the most of investigations was 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 the Iraqis, Dutch, Russians and the Americans, 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 was organized by Strachan in 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 period from 1954-1955 and then twice up to 1975, the Dutch founded experimental fields in Dujailah Region at highly saline soils. The complete field infrastructure included field-pipe drainage and irrigation system with hydrants was properly provided. The obtained results indicated that the applied leaching rate of 35 cm, reduced soil salt content up to 60 cm, for 10%. During the reclamation period, the following crops were cultivated: Wheat, Barley, Alfalfa, Berseem, 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*) proved to be convenient crops for reclamation production. Berseem, as the crop resistant to high soil salt content, gained very low yield.

Halomorphic soils of Serbia, the same as the equivalent once in the world, engrossed the significant vigilance of Serbian science. A part of examinations was done in the field of chemical amelioration by gypsum and lime and their influence to chemical characteristics of "Slatine". The objective of the investigations concerned applying of 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 at the achievement of the first yield, where crop production was unstable or insignificant.

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

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

- Initial salt leaching during the reclamation production.

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

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

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

The main tasks of the reclamation production are the following:

- Increasing the soil desalinization efficiency.
- Achievement of the adequate level of soil fertility by NPK and micro elements treatments.
- Humidification 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 the microbiological activities by activation of biochemical processes in soil.

The selection of the reclamation production optimal model was realized in accordance to:

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

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

2. MATERIAL AND METHOD

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

Taking water from Main Dujailah canal, through earth and then 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 were placed. Complete infrastructure, including field-pipe drainage at the depth of 2, 2 m and spacing of 65 an 75 m were installed too.

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

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

• 2.1. Optimal crop rotation model Analyses and Selection

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

- Soil salinity degree (soil salinity class).
- Level of crop salinity tolerance.
- Crops ameliorative worthy.
- Crop water requirements-consumptive use.

Reclamation crops economic value.

- Taking into consideration the above mentioned criteria, as well as the actual- designed agriculture production requirements for given natural, climate and soil conditions, the following reclamation crops were selected:

- Berseem, Alfalfa, Winter mixture, Summer mixture, Barley, Sweet clover, Sudan grass.

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

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

In the first year of the reclamation production all the selected crops were 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 which did not fulfil the anticipated criteria, 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 confirmed that the following crops did not fulfill the defined conditions and criteria, and consequently could not reach the second year of reclamation production: Bersim, Horse-been, Alfa-Alfa, winter and summer mixture.

2.1.1. 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 was applied. On the other hand, time and schedule of reclamation production implementation was 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 reclamation production, in accordance to the principle given in table

Table 1. Model A (Soil Salinity Class I, ECo< 20 mmhos/cm)

Crop Production Year	Growing season during the year	
	Winter (October-May)	Summer: (April-September)
1	Barley	Fallow
2	Sweet clover	Fallow
3	Regular Crop production	

During the first winter season after the initial salt leaching the 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 ploughed in. During the second year Sweet clover

green mass will be ploughed into the soil too. After that, complete area will be transferred into the Regular production.

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

Table 2. Model B (Soil Salinity Class II, $E_{Co} >20 < 40$ mmhos/cm)

Crop Production Year	Growing season during the year	
	Winter (October-May)	Summer (April-September)
1	Sweet clover	Sweet clover
2	Barley	Sudan grass
3	Regular Crop Production	

This crop rotation model includes initial soil salt leaching lasting 4 months. The reclamation production was 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 was ploughed, due to organic matter provision. During the summer period the whole area was placed under the fallow.

During the second winter season, the whole area was sown by crop of Barley. After the harvesting of Barley and stubble ploughed in, the land was converted to the fallow. Within the second summer season, the area was optionally transferred to fallow, or was sown by Sudan grass, depending on the availability of water required for additional salt leaching. At the end of the summer period Sudan grass was 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, $E_{Co} > 40$ 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 3. Model C (Soil Salinity Class III, $E_{Co} > 40$ mmhos/cm)

Crop Production Year	Growing season during the year	
	Winter (October-May)	Summer (April-September)
1	Sweet clover	Sweet clover
2	Barley	Suddan grass
3	Regular Crop Production	

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, the complete land area was cultivated and sown by Sweet clover. Vegetation of this crop was prolonged during the summer period of the second year. Second Sweet clover harvest was ploughed in and then the area was prepared for the second winter season and sowing of Barley.

During the second summer season, the complete area was 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. Analysis of reclamation crops production cultivation technology variants.

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

Stage I-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.

Stage II-land preparation for reclamation of crop production. In relation to crop type, salinity class, soil texture and stratigraphy, different soil preparation models were applied (Taylor, 1982). The following variants were analysed:

- Dismantling and planning of embankments and ditches backfilling.
- Both, variant with and without land levelling.
- Primary ploughing at 4 depths 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. Selection and evaluation of reclamation production irrigation methods

After the initial salt leaching process completion and sowing of reclamation 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 water quantities” were 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 reclamation crop production (Dieleman, 1973. Žeželj, 2013).

During the period of initial salt leaching the water is released into the cassettes-basins, while during the reclamation production crop vegetation water distribution was 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 were used and analysed:

- a. Surface irrigation methods: Border strip (overflowing) and cassettes- basins (flooding).
- b. Sprinkler irrigation methods: Application of self-driving equipment in variants with top-gun sprinklers and rain ramps (booms). Application of micro-jets small and medium range diameters.

For monthly reclamation crops water requirements estimation, the Blaney-Criddle method as competitive for the South-East Mesopotamian valley was 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-evapotranspiration 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. 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 reclamation 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

Crop	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Total
Barley		20	43	63	84	108	26						344
Sweet clover	159	82	49	47	59	100	162	268	336	356	333	245	1.860
Sudan grass							137	227	315	350	268		1.297

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

Month	Average Temperature ($^{\circ}C$)	Insolation	ET factor	Climatic Coeff.	Crop grow Coeff.	ET Coeff.	ET Month
April	29,2	9,62	6,36	1,23	0,9	0,85	137
May	33,3	9,60	8,13	1,28	0,9	1,10	315
June	35,1	9,77	8,87	1,34	1,0	1,40	315
July	31,7	9,28	9,33	1,33	1,1	1,47	350
August	25,8	8,34	8,81	1,23	0,9	1,20	268
Total Season							1.297

3. RESULTS AND DISCUSSION

Reclamation crop production analysis 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 following of the suggested models emphasizing the II desalinization stage-Reclamation crop production are presented and discusses herewith:

1. Out of 8 chosen crops (Berseem, Horse-been, Alfa-alpha, Winter and Summer mixture, Barley, Sweet clover and Sudan grass), after the first year of the reclamation production, it was stated that the first five did not fulfil the given criteria:

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 did not show the 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. Reclamation crops economic value criterion was not achieved too.

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. At the same time, the Barley provides rapid livestock production introduction.

Sweet clover is marked as the main reclamation crop, distinguished by the deep, robust and developed root system. Intensive and developed surface and underground vegetative mass provided 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 cultivated specifically as a summer season crop, for autumn green mass plough in. This culture gives rather high reclamation effects due to huge sub surface vegetative mass as well as by deep root system. It is 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.

2. Within the II land preparation stage for reclamation 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.

Reclamation production technology includes also an adequate crop care, protection and fertilization systems, taking into consideration a specific soil condition as well as biological and genetic figures of selected crop types.

3. Desalinization process continuity during the reclamation 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 represent the average monthly ET values for Sudan grass, as the dominant summer season crop. The highest ET value were noted in the 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 of consumptive use of the reclamation 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 reclamation production.

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

- Border strip irrigation (overflowing).
- Basin-cassettes 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 reclamation 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 reclamation production.

5. CONCLUSIONS

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

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

3. The selection of the reclamation production optimal model was 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 was applied.

5. The optimal technological procedures and land preparation measures as well as crop care and protection and fertilization system were 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 were achieved by the border strip irrigation methods application.

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

6. LITERATURE

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ANALIZA PRIMENE DIFERENTNIH MODELA PRELAZNE-REKLAMATIVNE PROIZVODNJE, USLOV KOMPLEKSNIH MELIORACIJA ZASOLJENIH ZEMLJIŠTA

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ABSTRAKT

Kompleksne melioracije zemljišta su sprovedene u okviru dve fundamentalne 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 zemljištaof (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-desalinizacije zasoljenih zemljišta.

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

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