ARBA MINCH UNIVERSITY
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CHAPTER THREE

SALT AND WATER LOGGED PROBLEM IN IRRIGATED AGRICULTURE

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3.1 Definition of salinity and water logged

WHAT IS SALINITY?

- Salinity is the accumulation of salts (often dominated by sodium chloride ($NaCl$)) in soil and water to levels that can have negative impacts on agriculture.

- Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in water stress for a significant period of time.

Cont…

- Salinity can have negative impacts on farmers productivity.

Some impacts include

- ✓ Reduced agricultural production
- ✓ Reduced farm income
- ✓ Reduced options for production
- ✓ Reduced water quality for livestock and irrigation use
- ✓ Reduced productivity of agricultural land, animal health problems

- **Example:-** saline water supply can result:
  - ✓ Farm machinery problems (rusting)
  - ✓ Breakdown of soil structure
  - ✓ Increased erosion and nutrient loss
  - ✓ Loss of beneficial native flora and fauna

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WHAT IS WATER LOGGING?

- Water logging is without question one of the most prevalent and serious problem associated with irrigation in arid regions of the world

- The excess of irrigation water application over and above evapotranspirtion losses will percolate below the crop root zone, eventually reaching the ground water table.

- The water table will in time rise, eventually to reach the crop root zone and even, in lower lying areas, the land surface.

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- Saturated or water logged soils are usually **damaging to crop yields** and the rising water table often leads to **salinization** , a further loss to crop production.

- When water is applied to a crop, most of the moisture leaves the soil through evaporation but **salts remain in soil**

3.2 Causes of salinity

WHAT CAUSES SALINITY?

- Salinity can be produced by the natural occurrence of salts in the landscape
  - ✓ For example salt marshes, salt lakes, tidal swamps or natural salt scalds.
- It can also be caused by irrigation with saline water
- Uneven water distribution
- Salts accumulated in the root zone and salinisation of root zone from shallow water tables
- Increased rates of leakage and groundwater recharge causing the water table to rise.

Cont…

- Rising water tables can bring salts into the plant root zone which affects both plant growth and soil structure.

- The salt remains behind in the soil when water is taken up by plants or lost to evaporation.

- During repeated irrigations, the salts in the irrigation water can accumulate in the soil, reducing water available to the crop and hastening the onset of a water shortage.

- Recharge rates in irrigation areas can be much higher than dryer areas due to leakage from both rainfall and irrigation.
- This potentially causes very high **salinisation rates**.

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- Water tables within two metres of the soil surface indicate the potential for salts to accumulate at the soil surface.

- Inefficient irrigation and drainage systems are a major cause of excess leakage and increase the risk of salinity and water logging in irrigation areas.

- Poor water distribution in **paddocks** results in some areas being under-irrigated, causing salts to accumulate (where water tables are high) and other areas being over-irrigated and waterlogged.

3.2.1 THE EFFECT OF SALT ON PLANTS AND SOIL

- Plants are adversely affected by salinity in several ways.
- The most important of these is the osmotic effect, which limits the ability of plants to take up water.

- Under normal conditions, plants readily obtain water from the soil by osmosis (movement of water from a lower salt concentration outside the plant to a higher salt concentration in the plant).
- As soil salinity increases this balance shifts making it more difficult for plants to extract water.

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- As a general guide, chloride and sodium ions in the salts do the most damage to plants.
- Irrigating with water high in these salts can be detrimental to plant growth, affect plant yields and ultimately threaten the plant's survival.

❖ Soil salinity has the following adverse impacts

- ✓ Which lead to poor plant health
- ✓ A loss of productive species and
- ✓ Dominance of salt-tolerant species

Cont…

- Increasing salt in the soil increases the osmotic pressure.
  - ✓ This results in reduced water availability and reduced growth.
- Some elements or ions, especially sodium (Na), chloride (Cl) and boron (B), when in excess are toxic to crops
- High proportions of sodium (Na) in relation to calcium (Ca) and magnesium (Mg) can adversely **affect soil structure**, and thus limit water, air and root movement in the soil
- Altered nutrient interactions e.g. reduced availability of some elements.

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- Water salinity impacts on plants and animals to varying degrees depending on their **salinity tolerance levels**.

- Symptoms vary with the growth stage, being more noticeable if the salts affect the plant during the **early stages of growth**.

- In some cases, **mild salt effects** may go entirely unnoticed because of a uniform reduction in growth across an entire field.
- The plant symptoms are similar in appearance to **those of drought**, such as wilting, or a darker, bluish-green color and sometimes thicker, waxier leaves.

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- Excess sodium accumulation in leaves can cause leaf burn, necrotic (dead) patches and even **defoliation**.
- Plants affected by chloride toxicity exhibit similar foliar symptoms, such as leaf bronzing and necrotic spots in some species.

Figure 1: Salinity toxic effect on citrus

Cont…

- Some crops such as barley, **wheat** and corn are known to be more sensitive to salinity during the early growth period than during germination and later growth periods.

- **Sugar beet** and **sunflower** are relatively more sensitive during germination, while the tolerance of **beans** may increase or decrease during different growth periods depending on the variety.

3.2.2 PRACTICES TO CONTROL SALINITY

1. Irrigation leaching

- A classic solution to salinity management in the field is through leaching accumulated salts below the root zone.

- This is often accomplished by occasional excessive irrigation applications to dissolve, dilute and move out the salts from root zone of the soil.

- The amount of excess irrigation application required (often referred to as the "leaching fraction")

Leaching depends upon the

- ✓ Concentrations of salts within the soil and
- ✓ water applied to accomplish the leaching.

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- In areas affected (or at risk of being affected) by salinity irrigation requires careful management.

- It is a good idea to seek professional advice before developing an irrigation system in these situations.

- Applying a leaching fraction can flush salts out of the topsoil.

- **Rainfall** may act as a leaching fraction.

- However, excessive leaching fractions can worsen the process of salinisation by causing the water table to rise, so they need to be carefully managed.

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- Where irrigation water quantity is limited, sufficient water for leaching may not be available.

- The combined problem of limited water volume and poor water quality can be particularly difficult to manage.
- Field drainage can be used to facilitate the leaching process.
- Site specific issues like:
  - Soil and water chemistry
  - Soil characteristics and
  - Field layout

✓ Should be considered in determining the best approach to accomplish effective leaching.

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2. Groundwater position

- To minimize the chances of salinity problems, the water table should be kept two metres or more below the soil surface.

- In some areas this is an issue that requires regional management, such as establishing spear points, tile drains or groundwater pumps to increase the depth of the water table.
- The water table should also be monitored over time to check if it is stable or rising.
- If the water table is high (within 2 m) then artificial **subsurface drainage** may be needed.

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- ✓ If water tables are not yet high but are rising, **subsurface drainage** may be needed in the future.

NB: It is also recommended to work on improving irrigation efficiency.

3. Improving drainage

- ✓ Improve drainage in saline areas, particularly if salinity problems are associated with a rising water table and saline groundwater.
- ✓ If soils are waterlogged, removing excess water can help filter of salt from the root zone to lower levels in the soil profile.
- ✓ Consideration must be given to management of the drainage water.

4. Irrigation scheduling

- ✓ Managing irrigation schedules (amounts and timing) helps to keep salt accumulations dispersed and away from plant roots, provides for better root uptake of nutrients, and offers improved protection from short-term drought conditions

5. Minimize application of salts

- ✓ An option to minimize the effects of salinity is to **minimize irrigation applications** and the subsequent accumulation of salts in the field.

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- ✓ This can be accomplished through converting to a **rainfed production system**; maximizing effectiveness of precipitation to reduce the amount of irrigation required; adopting highly efficient irrigation and tillage practices to reduce irrigation applications required

- ✓ Using a higher quality irrigation water source (if available).

6. Crop selection

- ✓ Some relatively salt tolerant crops (such as barley and wheat) are more salt sensitive at emergence and early growth stages than in their later growth stages.

3.3 Cause of water logging

- Water logging is the rise of water table which may occurs due to
  - ✓Over and intensive irrigation
  - ✓Seepage of water from the adjoining high lands
  - ✓Seepage of water through the canals
  - ✓Impervious obstruction
  - ✓Inadequate natural drainage
  - ✓Inadequate surface drainage
  - ✓Excessive rains
  - ✓Submergence due to floods
  - ✓Irregular or flat topography

Water logging control

- It is evident that water logging can be controlled only if the **quantity of water** in to the soil below is **checked and reduced**.

- To achieve this, the inflow of water in to the underground reservoir should be reduced and the out flow from this reservoir should be increased as to keep the highest position of water table at least about **3m below** the ground surface

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- The various measures adopted for controlling water logging are:-

1. Lining of canals and water courses:-

- Attempts should be made to reduce the seepage of water from the canal water courses

2. Reducing the intensity of irrigation:-

- In areas where there is possibility of water logging, intensity of irrigation should be reduced

3. By introducing crop rotation:-

- certain crops require more water and other require less water
- If field is always sown with a crop requiring more water, the chance of water logging is more.
- In order to avoid this, a high water requiring crop should be followed by one requiring less water and then by one requiring almost no water

- **Example:-** rice may be followed by wheat and wheat may be followed by a dry crop such as cotton

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4. By optimum use of water:-

- It is known fact only a certain fixed amount of irrigation water gives best productivity

5. By providing intercepting drains:-

- Intercepting drains along the canals should be constructed whenever necessary
- This drains can intercept and prevent the seeping canal water from reaching the area likely to be water logged

6. By provision of an effective drainage system:-

- An efficient drainage system should be provided in order to drain away the storm water and the excess irrigation water
- The good drainage system consists of surface drain as well as sub- surface drain

3.4 Reclamation of saline and alkaline lands

- The term "alkali soil" means land that is saline, that has an excess of adsorbed sodium, or both.
- White alkali is due to an excess of neutral salts, usually sulphates and chlorides.
- An excess of sodium chloride gives a hard, firm surface crust with cubical salt crystals.

Cause of alkali soils

- ✓ The primary cause of alkali soils is a **high water table with poor drainage**.
- Arid soils, especially those from sedimentary rocks, are unleached; and certain soluble salts, which may be concentrated in seepage or ground water, move to the surface, and evaporate.

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- ✓ Impeded drainage
- ✓ Intermittent wetting with saline irrigation water
- ✓ Intensive evaporation due to aridity
- ✓ Accumulation of salt by wind all contribute to formation- of alkali land.

- Soil surveys may classify alkaline soils into those that are slightly, medium, and strongly alkaline, the classification being based on
  1. Total salt content and
  2. Reaction value, or pH.
- A pH of 7.0 represents neutrality.

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- Soil pH is a measure of the acidity and alkalinity in soils.
- **pH levels** range from 0 to 14, with 7 being neutral, below 7 acidic and above 7 alkaline.
- The optimal pH range for most plants is between 5.5 and 7.0; however, many plants have adapted to thrive at pH values outside this range.
- **Test the Soil pH With a Digital pH Meter**


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- To **test** your **soil's pH**, all you need is a **soil** sample, distilled water and **litmus paper** (from a hobby shop or science supply store).
- Mix a small bit of **soil with** the distilled water and touch the **litmus paper** to the **soil**-water solution.

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- Saline soil may be defined as having a pH below 8.5 and a soluble salt content of 1,000 to 2,000 or more parts per million.

How reclamation works???

- With **deep drainage** and adequate irrigation **water of good quality**, salty soils that are not heavy in texture can be washed out.
- **Chemical treatment** and restoration of permeable soil structure is necessary before laundering can succeed.

- This development is favored by periodic leaching with rain water in the presence of soluble lime.

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- Various scientists have used different methods in the field to evolve an easy and economic reclamation using use gypsum, sulphur, sulphuric acid, iron and aluminium and farm yard manure.
- Gypsum has been used by several scientists .
- Semcendyera, H.V. while studying the effectiveness of gypsum to low sodium affected soils, observed that calculated amount of gypsum had improved the soil fertility and the crop yield.
- Berg and Westrhot in Netheriand studied reclamation using gypsum.
- The structural deterioration of soil was minimized by application of gypsum

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- Prather and co-workers have studied reclamation of sodic soils using three chemical amendments $CaSo_4$, $CaCl_2$ and H_2So_4.

- As single amendment H_2S0_4 was more effective than $CaS0_4$ Combining either $CaCl_2$ or H_2S0_4 with $CaS0_4$ appreciably reduced the time and leaching needed to achieve reclamation, compared with $CaSo_4$ alone.

- Sharma and Mehrotra used waste H_2S0_4 on saline soils of Kanpur and compared the results with gypsum treatment Sharma and co-workers carried out reclamation with gypsum and suggested that the best improvement taken place in case of H_2SO_4

3.5 Quality of irrigation water

- Just as every water is not suitable for human beings in the same way, every water is not suitable for plant life.
- Water containing impurities which are injurious to plant growth, is not satisfactory for irrigation and is called the unsatisfactory water
- The quality of suitable irrigation water is very much influenced by the constituents of the soil which is to be irrigated.
- Nearly all waters contain dissolved salts and trace elements, many of which result from the natural weathering of the earth's surface.
- In addition, drainage waters from irrigated lands and effluent from city sewage and industrial waste water can impact water quality.

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- The various types of impurities which make the water unfit for irrigation are classified as
    i. Sediment concentration in water
    ii. Total concentration of soluble salt in water
    iii. Proportion of sodium ions to other cations
    iv. Proportion of potentially toxic elements present in water
    v. Bicarbonate concentration as related to the concentration of calcium plus magnesium
    vi. Bacterial concentration

- The effect of these impurities are discussed below

i. Sediment

- The effect of sediment present in the irrigation water depends up on the type of irrigate land.
- When fine sediment from water is deposited on sandy soils the fertility is improved.
- On the other hand if the sediment has been derived from the eroded areas it may reduce the fertility or decrease the soil permeability.

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ii. Total concentration of soluble salt in water

- In most irrigation situations, the primary **water quality concern is salinity levels**, since salts can affect both the soil structure and crop yield.
- However, a number of trace elements are found in water which can limit its use for irrigation.
- Generally, “salt” is thought of as ordinary table salt (sodium chloride).
- However, many types of salts exist and are commonly found in waters

Cont…

- **A complete water quality analysis will include the determination of:**

1. The total concentration of soluble salts,
2. The relative proportion of sodium to the other cations,
3. The bicarbonate concentration as related to the concentration of calcium and magnesium, and
4. The concentrations of specific elements and compounds.

Table 1. Kinds of salts normally found in irrigation waters, with chemical symbols and approximate proportions of each salt.[1] (Longenecker and Lyerly, 1994)

Chemical name	Chemical symbol	Approximate proportion of total salt content
Sodium chloride	$NaCl$	Moderate to large
Sodium sulfate	Na_2SO_4	Moderate to large
Calcium chloride	$CaCl_2$	Moderate
Calcium sulfate (gypsum)	$CaSO_4$ $2H_2O$	Moderate to small
Magnesium chloride	$MgCl_2$	Moderate
Magnesium sulfate	$MgSO_4$	Moderate to small
Potassium chloride	KCl	Small
Potassium sulfate	K_2SO_4	Small
Sodium bicarbonate	$NaHCO_3$	Small
Calcium carbonate	$CaCO_3$	Very Small
Sodium carbonate	Na_2CO_3	Trace to none
Borates	BO^{-3}	Trace to none
Nitrates	NO^{-3}	Small to none

[1]Waters vary greatly in amounts and kinds of dissolved salts. This water typifies many used for irrigation in Texas.

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Two Types of Salt Problems

- Two types of salt problems exist which are very different:
  - ✓ Those associated with the total salinity and
  - ✓ Those associated with sodium.

- Soils may be affected only by salinity or by a combination of both salinity and sodium.
- Water with high salinity is toxic to plants and poses a **salinity hazard.**

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- Water salinity is usually measured by the TDS (total dissolved solids) or the EC (electric conductivity).

- **TDS** is sometimes referred to as the total salinity and is measured or expressed in parts per million (ppm) or in the equivalent units of milligrams per liter (mg/L).
- Hence the effects of salts on plant growth depend largely upon the total amount of salts present in the soil solution.

- The critical salt concentration in the irrigation water depends upon many factors yet however, amounts in excess of 700 ppm are harmful to some plants and more than 2000 ppm are injurious to all crops

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- The salinity concentration of the soil solution (Cs) after the consumptive water (Cu) has been extracted from the soil, is given by

$$C_s = \frac{C \cdot Q}{[Q - (C_u - P_{eff})]}$$

where Q = The quantity of water applied

C_u = Consumptive use of water, *i.e.* the total amount of water used by the plant for its growth

P_{eff} = Useful rainfall

$C_u - P_{eff}$ = Used up irrigation water

C = Concentration of salt in irrigation water

CQ = Total salt applied to soil with Q amount of irrigation water.

Cont…

S. No.	Type of water	Use in irrigation
1.	Low salinity water (C1). Conductivity between 100 to 250 micro mhos/cm at 25°.	Can be used for irrigation for almost all crops and for almost all kinds of soils. Very little salinity may develop, which may require slight leaching; but it is permissible under normal irrigation practices except in soils of extremely low permeabilities.
2.	Medium salinity water (C2). Conduc- tivity between 250 to 750 micro mhos/cm at 25°C.	Can be used, if a moderate amount of leaching occurs. Normal salt-tolerant plants can be grown without much salinity control.
3.	High salinity water (C3). Conductivity between 750 to 2250 micro mhos/cm at 25°C.	Cannot be used on soils with restricted drainage. Special precautions and measures are undertaken for salinity control and only high-salt tolerant plants can be grown.
4.	Very high salinity water (C4). Conductivity more than 2250 micro mhos/cm at 25°C.	Generally not suitable for irrigation.

Cont…

iii. Proportion of sodium ions to other cations

- Most of the soils contain calcium and magnesium ions and small quantities of sodium ions.
- The percentage of the sodium ions is generally less than 5% of the total exchangeable cations.
- If this percentage increases to about 10% or more the aggregation of soil grains break down.
- The soil becomes less permeable and of poorer tilth.
- It starts crusting when dry and its pH increases towards that of an alkaline soil.
- High sodium soils are therefore plastic, sticky when wet, and prone to form clods, and they crust on drying.

Cont…

- Sodium Hazard Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on the soil and poses a sodium hazard.
- Sodium hazard is usually expressed in terms of SAR or the sodium adsorption ratio.
- SAR is calculated from the ratio of sodium to calcium and magnesium.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where, the concentration of the ions is expressed in equivalent per million (epm) ; epm is obtained by dividing the concentration of salt in mg/1 or ppm by its combining weight (*i.e.* Atomic wt. ÷ Valence.)

Cont…

S. No.	Type of water	Use in irrigation
1.	Low sodium water (S1). SAR value lying between 0 to 10.	Can be used for irrigation on almost all soils and for almost all crops except those which are highly sensitive to sodium, such as stone-fruit trees and adocados, etc.
2.	Medium sodium water (S2). SAR value lying between 10 to 18.	Appreciably hazardous in fine textured soils, which may require gypsum, etc. ; but may be used on course-textured or organic soils with good permeability.
3.	High sodium water (S3). SAR value lying between 18 to 26.	May prove harmful on almost all the soils, and do require good drainage, high leaching, gypsum addition etc. for proper irrigation.
4.	Very high sodium water (S4). SAR value above 26.	Generally, not suitable for irrigation.

Cont…

Classification of saline and alkaline soils

Sl. No.	Classification	Electrical Conductivity (EC) in micro-mho/cm	Exchangeable Sodium Percentage (ESP)	pH value
1.	**Saline soil** or *white alkali*	> 4000	< 15	≤ 8.5
2.	**Alkaline soil** or *Non-saline alkali* or *Sodic soil* or *Black alkali*	< 4000	> 15	8.5 to 10.0
3.	*Saline-alkali soil*	> 4000	> 15	< 8.5

Example

- What is the classification of irrigation water having the following characteristics concentration of Na, Ca and Mg are 22, 3 and 1.5 milli-equivalents per litre respectively, and the electric conductivity is 200 micro mhos per centi meter at 25^{o}c what problems might arise in using this water on fine textured soils? And what remedies do you suggest to overcome this trouble?

iV. Proportion of potentially toxic elements present in water

- A large number of elements such as boron, selenium etc. may be toxic to plants.

- Traces of Boron are essential to plat growth, but its concentration above 0.3 ppm may prove toxic to certain plants.

- The concentration above 0.5 ppm is dangerous to nuts, citrus fruits and deciduous fruits.

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- Cotton, Cereals and certain truck crops are moderately tolerant to boron, while Dates, Beets, Asparagus etc. are quite tolerant.

- Even for most tolerant crops the boron concentration should not exceed 4 ppm. Boron is generally in various soaps.

- The waste water containing sop should therefore, be used with great care in irrigation.

- Selenium even in low concentration is toxic and must be avoided.

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V. Bicarbonate concentration as related to the concentration of calcium plus magnesium

- High concentration of bi-carbonate ions may result in precipitation of calcium and magnesium bicarbonates from the soil-solution, increasing the relative proportion of sodium ions and causing sodium hazards.

Vi. Bacterial concentration

- Bacterial concentration of irrigation water is not a serious problem, unless the crops irrigated with highly contaminated water are directly eaten without being cooked.
- Cash crops like cotton, nursery stock, etc. which is processed after harvesting can therefore use contaminated waste waters, without any trouble.

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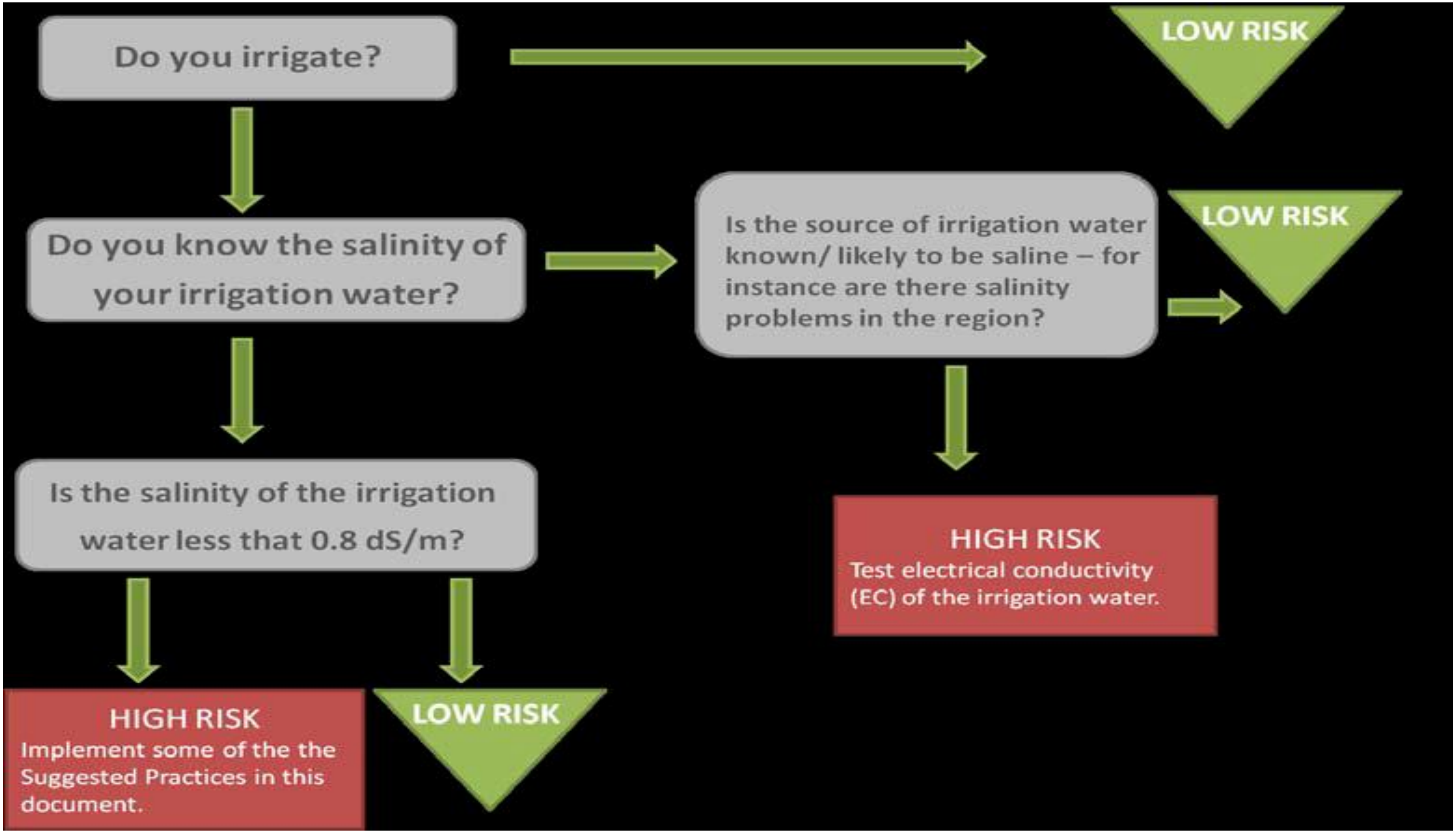
- **The following diagram can help farmers to assess a significant salinity problem in the farm area.**



Thank You!!!