Exploring Genetic Algorithms for improved salinity management using SWAMP

BO Haile, B Grové, J Barnard, LD van Rensburg

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SANCID

T: 051 401 9111 info@ufs.ac.za www.ufs.ac.za

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OUTLINE OF PRESENTATION

- The presentation will have the following format:
  - Background and Motivation
  - Problem statement and objectives
  - Procedures
  - Results and Discussions
  - Conclusions /Future explorations

1. BACK GROUND AND MOTIVATION

- Growing scarcity of water, growing populations, & varying natural conditions puts pressure in irrigation systems (Sadati et al., 2014; Scütze et al., 2012; Van Rensburg et al., 2012).
- Salinity :

  - a great hindrance for agricultural production under irrigation (Van Rensburg et al., 2012; Dominguez et al., 2011).

  -causes poor crop quality and diminishing economic yield (Dominguez et al., 2011; Armour, 2007).

  -impact to the environment via salt transport through river systems (Barnard et al., 2014; Van Rensburg et al., 2012; Ehlers et al., 2007).

  -degrades water resources and land resources

  -can affect seed germination, seedling growth, vigour vegetative growth, flowering and fruit (seed) production.

CONT. BACKGROUNDS....

- **According to Van Rensburg et al. (2012) estimated fraction of salt-affected irrigated land In South Africa is about 9%.**
- **Salinity problem areas in SA include:**

  -e.g. Breede, Olifants, & Orang-Vaal-Riet rivers.
- **Study was applied to :**

  -Orange-Riet & Vaalharts irrigation schemes.

  -irrigation is being performed for more than 70 years on both schemes

  -shallow water tables

2. PROBLEM STATEMENT & OBJECTIVES

- In the Vaalhars irrigation schemes, irrigation has been performed for long decades and there is increasing evidence of declining of natural resources and hence the problem of salinity cannot be ignored (Barnard et al., 2014; Van Rensburg et al., 2012; Ehlers et al., 2007; Armour, 2007).
- There is a shallow water table in most part of the irrigation schemes.
- There are considerable evidence (Van Rensburg et al., 2012; Ehlers et al., 2007; Armour, 2007) that show most farmers in the irrigation schemes do irrigate their farm according to the water requirements of the field crops. This implies:

  -continuous leaching of salt from the soil profile (over-irrigate),

  -no consideration of water table uptake by the plant by the farmers in their irrigation strategy.

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CONT. PROBLEM ....

- The main objectives of the study is to develop a model which optimizes the irrigated water taking in to consideration water stress, salt stress, and the possibility of water uptake from shallow water table so as to come up with a best irrigation strategy to the management of water and salt in irrigated farms taking into account farm profitability.

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CONT. OBJECTIVES

- **The optimization was done by testing scenarios for the simulation as well as for the Genetic Algorithms to analyze:**

  -the strategy of irrigating the farm with ET potential

  (over-irrigation, percolation) 🡐(shallow water table)

  -the benefit of considering water table uptake.

  - Strategy 1: simulation with SWAMP was conducted for irrigating the field to meet the crop water requirement (ETp) of the crop with low EC and high EC irrigation water in alternative case of soil with initial low & high salinity .

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CONT. OBJECTIVES

- **Strategy 2:** Optimisation of SWAMP was conducted for the crop with low EC and high EC irrigation water in alternative case of soil with initial low & high salinity.
- Simulation and the GA were run for:

  -Maize crop

  -Soil: Bainsvlei Type

  -reasonable prices for output and water cost for irrigation.

  -Water table EC=200 (m per Sm)

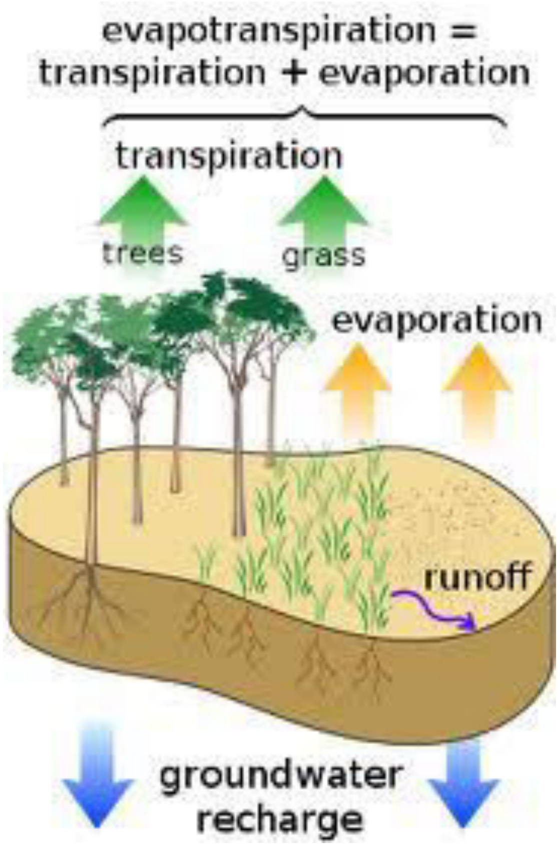
  -several measured and default parameters (SWAMP)

3.1 GENERAL OVERVIEW OF SWAMP

-it is the result of advanced research to the management of water and salt on irrigated farms (Barnard et al., 2013; Van Rensburg et al. 2012)

-takes into account the complexity & integrated nature of the processes involved (e.g. root zone salinization, irrigation and natural and/or artificial drainage in water table soils (Van Rensburg et al. 2012).

-it is different from other salt models (such as SWAP,SALTMED, HYDRUS) as it does not require salinity threshold and slope parameters to simulate water and salt stress in the Model (Barnard et al., 2013; Van Rensburg et al. 2012).



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CONT. SWAMP

- **The model simulates daily changes in water content of a multi-layer(k) soil & seasonal influence on crop yield.**
- **<u>Water Budget (water flow):</u>**

  -based on cascading principle on a daily basis.

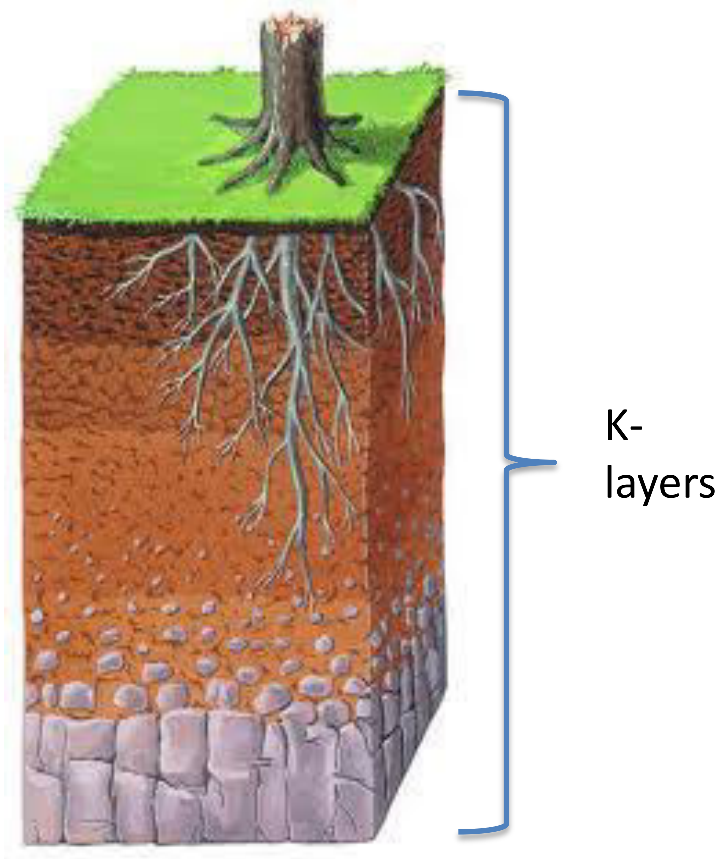
  -Drained Upper limit (DUL)

  -Profile Water Supply Rate (PWSR)

  -Layer Water Supply Rate(LWSR)

$$PWSR(d) = \sum_{k=1}^{n} LWSR_{(k)(d)}$$

$$LWSR(k)(d) = Fsr * \ln\left(\frac{\theta_{(k)(d)}}{\theta_{T(k)(d)}}\right) * \pi Lv^{0.5} * \left|\varphi_{T(k)(d)} - \varphi_p\right| * Z_{(k)}$$



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CONT. SWAMP

- **Water balance**

$$DF(k)(d) = (\theta DUL_{(k)(d)} - \theta_{(k)(d)})Z_{(k)}$$

$$INF_{(k)(d)} = EF_{(R+I)(d)}$$

$$INF_{(k)(d)} = INF_{(k-1)(d)} - DF_{(k-1)(d)}$$

$$AP_{(k)(d)} = DF_{(k)(d)} \text{ when } INF_{(k)(d)} > DF_{(k)(d)}$$

$$AP_{(k)(d)} = INF_{(k)(d)} - OTF_{(k)(d)} \text{ when } INF_{(k)(d)} < DF_{(k)(d)}$$

$$INF_{(k+1)(d)} = OTF_{(k)(d)} = INF_{(k)(d)} - DF_{(k)(d)}$$

- **Salt balance**
- **The soil-root hydraulic gradient must include the total water potential :**

$$\varphi_T = \varphi_{(m)} + \varphi_{(o)}$$

- **To determine total water potential for each layer on every day an arbitrary total water potential was incrementally reduced from saturation and the corresponding matric potential calculated from the retention curve.**

3.2 EVOLUTIONARY ALGORITHMS /COMPUTATIONS

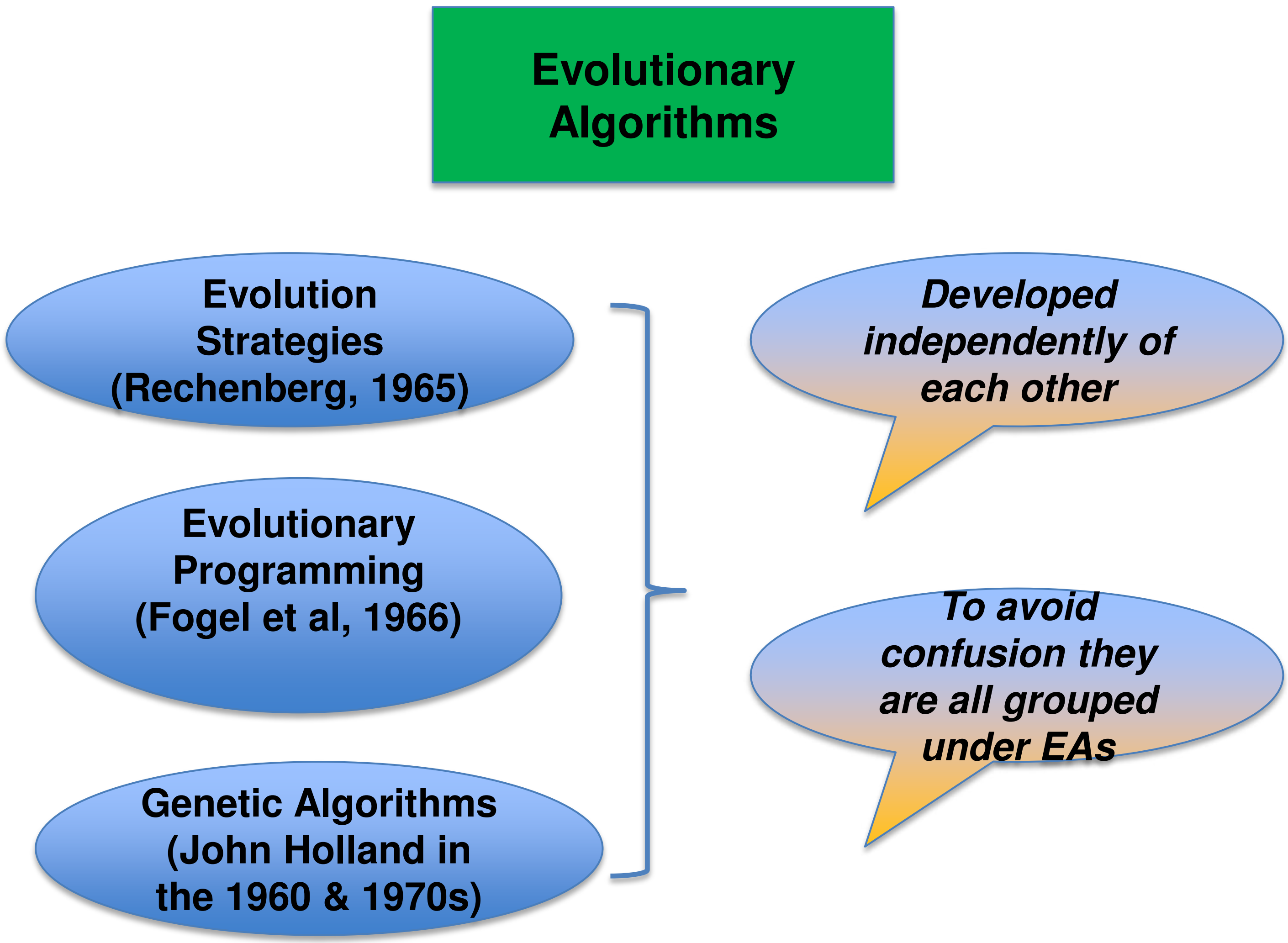
- **Evolutionary Algorithms:**

  -refers to a class of stochastic search and optimization methods (Sivanandam and Deepa, 2008; Haupt and Haupt, 2004;Spall, 2003).

  -are based on the mechanics of natural selection and natural genetics (Schütze and Schmitz, 2010; Spall, 2003)

  - “survival of the fittest “ concept [Darwin’s Theory of Evolution]

  - their use for solving real-world problems become of interest only in the last decade.


Evolutionary Algorithms
Evolution Strategies (Rechenberg, 1965)
Evolutionary Programming (Fogel et al, 1966)
Genetic Algorithms (John Holland in the 1960 & 1970s)
Developed independently of each other
To avoid confusion they are all grouped under EAs

GENETIC ALGORITHMS

- GAs refers to a global optimization techniques which are based on population-based approach to optimization (Schütze and Schimitz, 2010, Rana, Khan, and Rahami, 2008; Spall, 2003).
- Main reasons for using GAs:

  -their ability to deal with non-linear complex optimization problems (Oyebode et al, 2014;Schütze et al. 2012; Van Dijk, 2008).

  -their broad applicability, flexibility, and their ability to find solutions with relatively modest computational requirements (Rana et al 2008).

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CONT. GENETIC ALGORITHMS

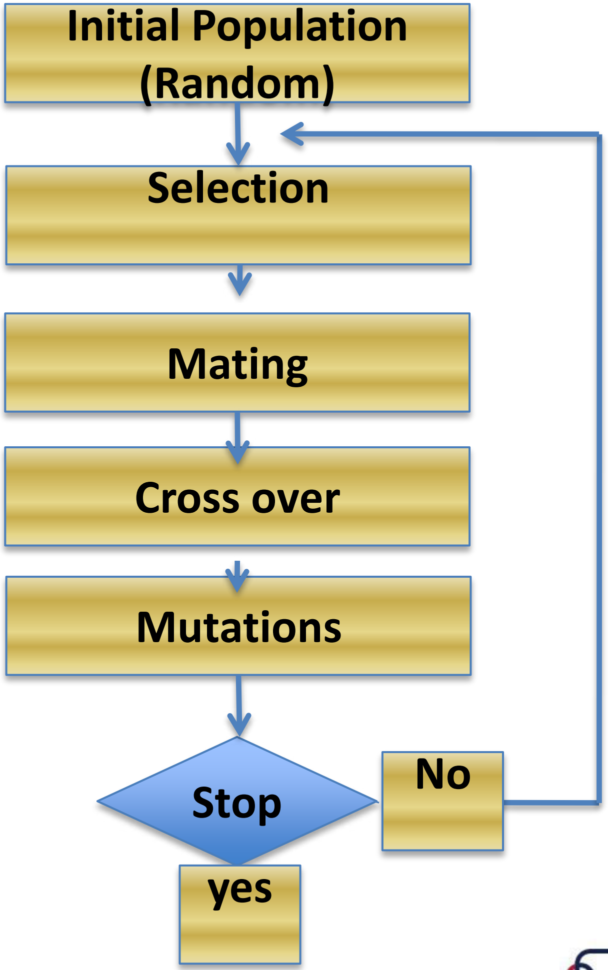
- The fundamental steps of a GA may be reduced to:

  -**Initialization** (random)

  -**Mixing** (according to principles of evolution to produce a new set of populations)

  -**Evaluation** (measure of performance of the new population values)

- Schematic Diagram of GA



SOME APPLICATIONS OF GENETIC ALGORITHMS TO IRRIGATION PROBLEMS

- **International**

  -irrigation scheduling problems (Schütze et al. 2012; Haq & Anwar, 2010; Anwar & Haq, 2013),

  -salinity related problems (Rana et al., 2008; Rajkumar & Thompson, [no date]),

  -minimizing water & energy consumptions (Gracia et al., 2013; Moradi-Jalal, 2004),

  -problems of irrigation as related to climate change (Cobo et al., 2014; Schütze & Schmitz, 2010),

  -water allocating policies (Sadati et al. 2014;Kumar et al., 2006),

  -crop-planning problems(Sarker & Ray, 2009; Faramani et al., 2007)

  -water-distribution net work design (Jolns et al., 2014)

- **South Africa**

  -in optimizing water distribution systems (Van Dijk et al, 2008; Ndiritu, 2005).

  -reservoir system optimization to maximize yield (Ndiritu,2003).

  -in prediction of stream flow using EAs (Oyebode, Adeyemo, & Otieno, 2014).

4. RESULTS AND DISCUSSIONS

	Simulate L80	Optimal L80_GA	Simulate L500	Optimal L500_GA
I(mm)	737	300	737	540
E(mm)	132	41	134	51
T(mm)	645	645	611	623
WTU(mm)	297	344	303	335
D(mm)	230	0	268	219
Salt_Start (kg/ha)	4121	4121	4121	4121
Salt_End (kg/ha)	4982	11082	14203	20466
Y(kg/ha)	12614	12607	11956	12193
MAS R/ha	22649	24164	21334	22496

- **Strategy S1 & S2 with low soil salinity case:**

L80

-high Percolation & less Salt built up

L80_GA (Optimal)

-low Irrig, no Percolation, with high salt built ups, & better MAS as compared to L80

L500

-impact of stress on yield is evident

L500_GA (Optimal)

-some decline in percolation as compared to L500

-improve in Y & MAS

****<u>Low ECi & EC soil</u>: GA more about optimal yields & try to reduce percolation**

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CONT. RESULTS…

	Simulate H80	Optimal H80_GA	Simulate H500	Optimal H500_GA
I(mm)	737	345	737	660
E(mm)	133	46	135	66
T(mm)	645	644	605	625
WTU(mm)	297	334	300	323
D(mm)	230	35	270	310
Salt_Start (kg/ha)	8242	8242	8242	8242
Salt_End (kg/ha)	5006	13298	22088	20451
Y(kg/ha)	12614	12605	11838	12226
MAC	22649	24002	21099	22143

- **Strategy S1 & S2 with high salinity case:**

H80

-percolation helps leach out salt

-similar T with H80_GA

H80_GA (Optimal)

-huge decline in percolation

-increase in MAC

-salt built up

H500

-stress on Y & due to high salt built up

H500_GA (Optimal)

-increase in Percolation with improved salt concentration than H500

**High EC soil: GA is more about managing salinity (increase in P and decrease in E)

**Environmental impact increase if EC of irrigation & soil increases.

5. CONCLUSIONS & FURTHER RESEARCH

- GA as an optimization procedure for this problem seems promising.
- The optimization of SWAMP (for single crop & single season) gives irrigation strategies with better MAS (Gross margin above specified cost) than the farmers strategies in all cases of scenarios considered in the study.
  - Increase in salt balances if salinity is not affecting crop yield
  - When crop yield is affected by salinity levels optimal management of salinity levels will reduce salt accumulation
- SWAMP is based on yield relationship based on seasonal transpiration.
  - Need to test yield models that are sensitive to stress at different growth stages of the crop(e.g. Stewart multiplicative model).
- Salinity is a long term process, so need an optimization model to take into account long term salt built up in the soil profile.

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Thank You
Dankie

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