Sultan Qaboos University

مجلس البحث العلمي
The Research Council

Institutional Approaches for Groundwater Management in Coastal Aquifers- An Empirical Analysis

Abstract # 2142

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25-29th September 2016
Montpellier, France
CORUM CONFERENCE CENTER
43rd IAH congress

Introduction

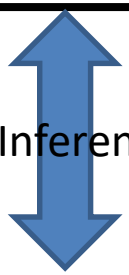
- Excessive groundwater (GW) pumping is a global problem
- The coastal areas of Oman are primarily concerned
  - GW over-pumping resulted in seawater intrusion
  - Irreversible degradation of the unique renewable water resource
- Several measures have been implemented in the past
  - Diffusion of water-saving technology
  - Recharge dams
  - Re-use of treated wastewater for landscaping
  - Transfer of the large producers of Rhodes grass to Nejed area
- However: GW levels continues to decline and seawater intrusion is steadily progressing in most of the coastal areas.
- Root of the problem: GW is a common resource pool
  - Absence of exclusivity and the
  - Lack of incentives for farmers to save water due to the open access nature of the resource
- Changing human behavior is difficult to accomplish. The goal of this project is to establish better ways to reach and implement sound decisions to ensure sustainability.

The world is changing
Aquifers' management is not

- GW Salinity is invisible and silent like cancer
  - It takes a long time for effects to be observed
  - Once there, the disease is almost irreversible
  - The treatment is costly and painful
- GW salinity causes are NOT NEW
- Transform the way Aquifers & Farms are managed
  - Property rights: Who? How much? When?
  - Legal framework
  - Technology: metering, smart irrigation, marketing…
- An integrated hydro-economic approach to deal with groundwater optimal exploitation and allocation among farmers to minimize salinization

Methodology

MODFLOW GW simulation model
1-Quantity
&
2- Quality



Bayesian Inference System

Dynamic optimization model
70 years

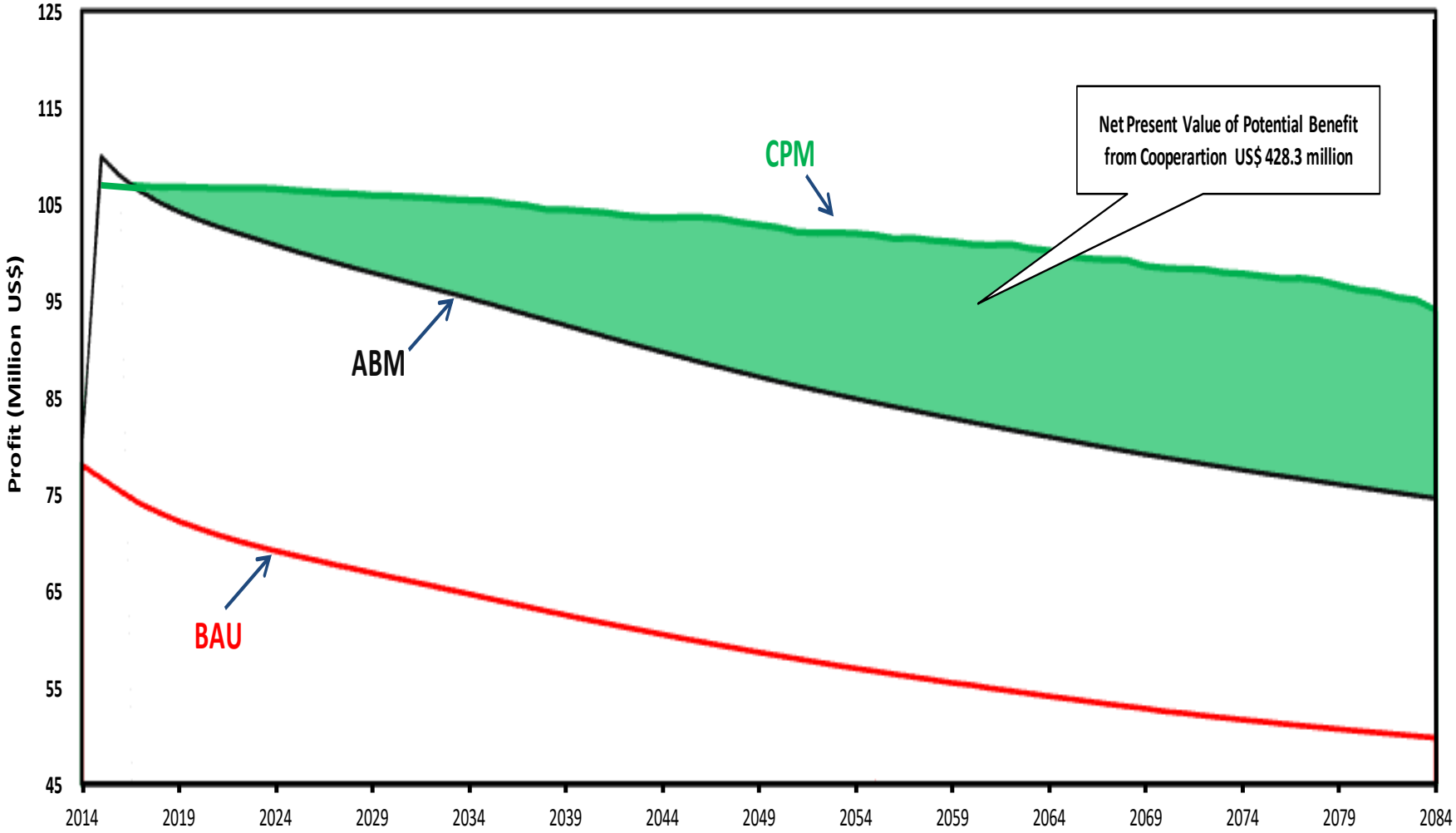
Methodology
70 years cycle

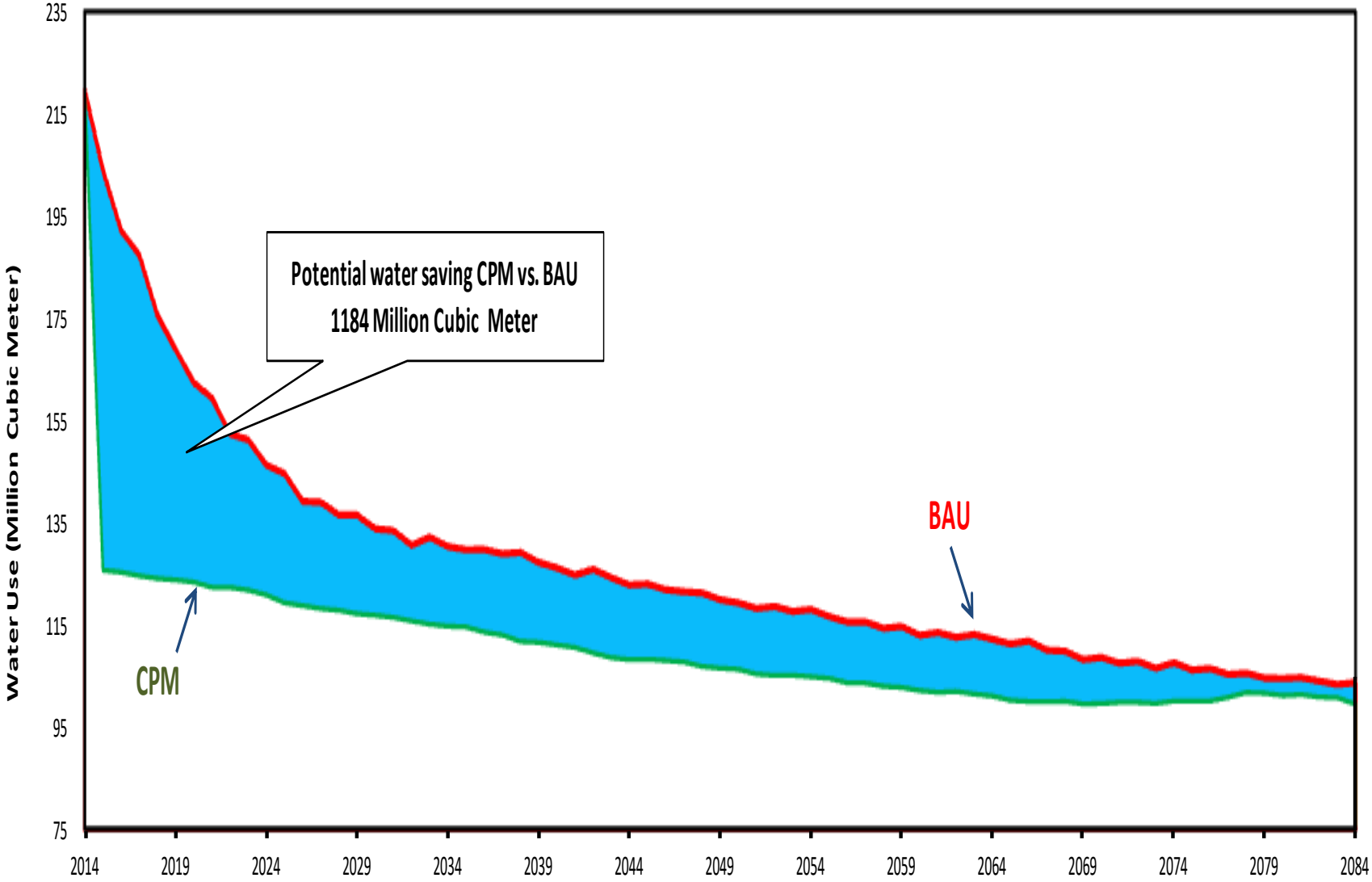
- 2 dynamic optimization models are developed.
  - 1st model: Optimizes groundwater management at the farm level. Agent Based Model 8,000 farms **ABM**
    - GW pumping is decentralized and uncoordinated
  - 2nd model: Optimizes the centralized management.
    - One decision maker for the 8000 farms and the aquifer **CPM**
      - Ideal situation if farmers are looking for collective efficiency.
      - Decisions are coordinated integrating salinity and profit in long-term

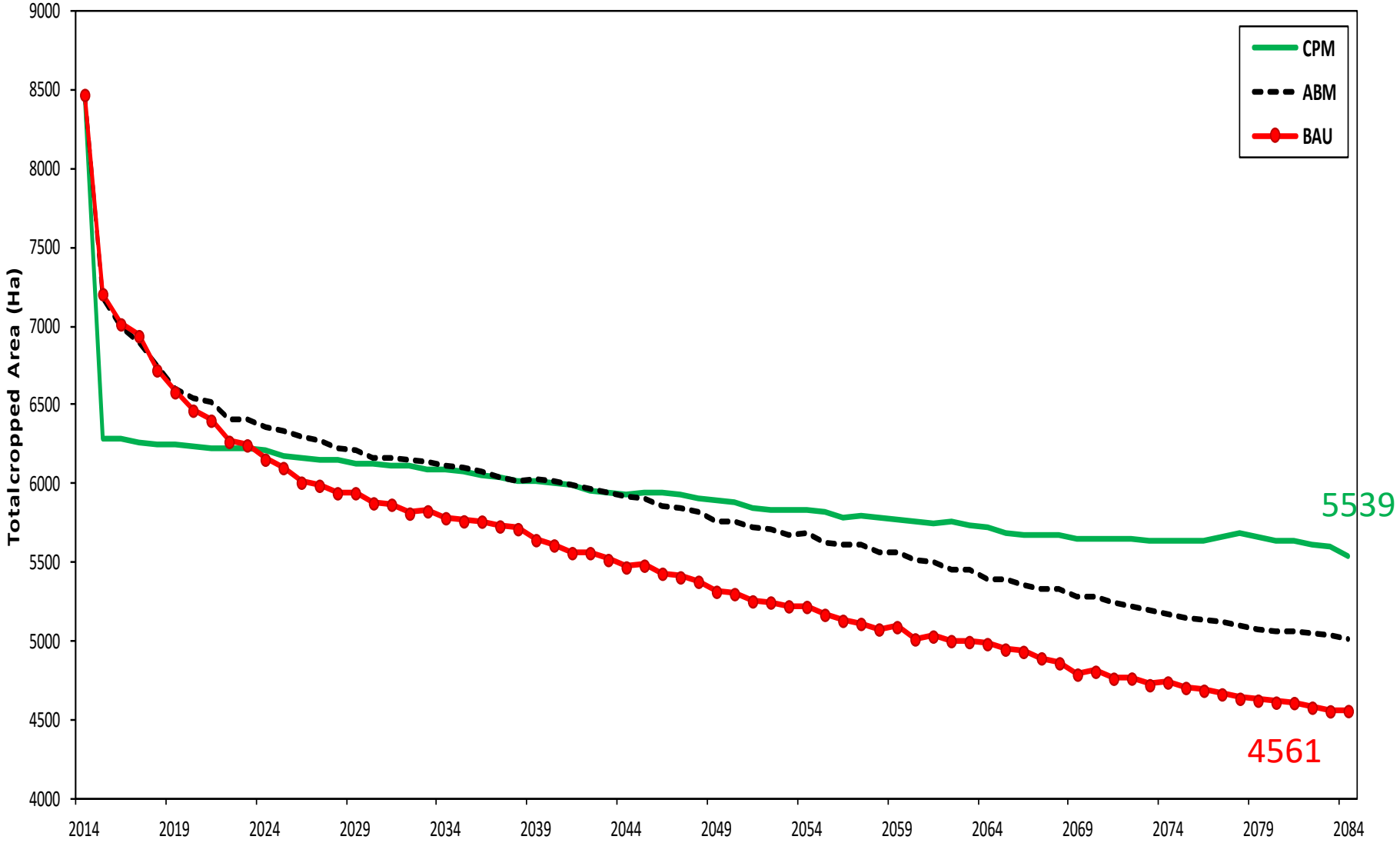

500 km
Iran
Persian Gulf
Bahrain
Qatar
Gulf of Oman
United Arab Emirates
Oman
Google

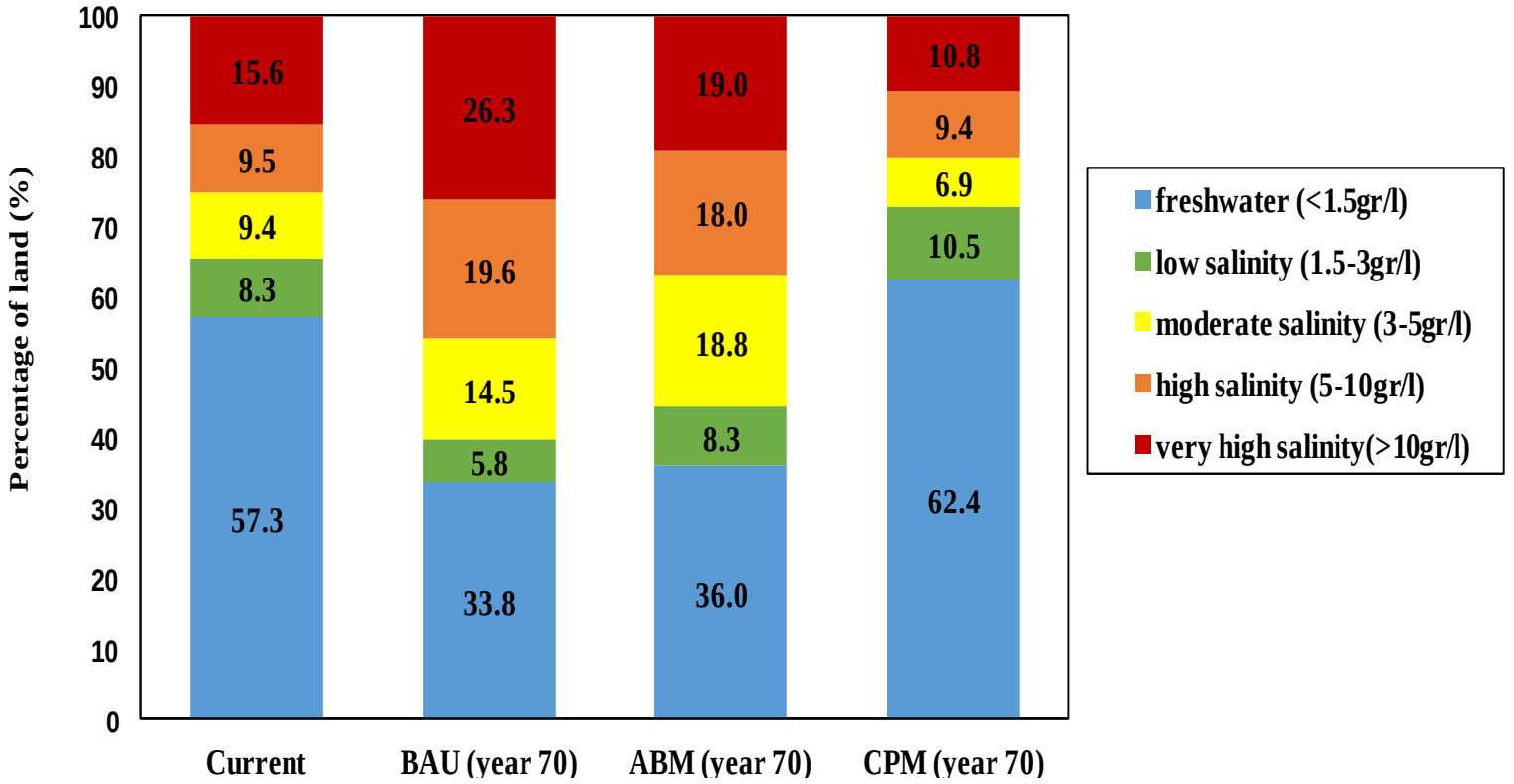

OMAN SEA
Wilayat Center
Main Road
Project Area
Agriculture
Shinas
Sohar
Saham
Al Khaburah
As Suwayq
Al Musannah
Barka
Batinah Coastal Plain
SHINAS
LIWA
SOHAR
AL KHABURAH
AS SUWAYQ
MUSANAAH
BARKA
NAKHAL
WADI AL MAAWIL
Nakhal
Ar Rustaq
Al Awabi
AR RUSTAQ
0 5 10
KM

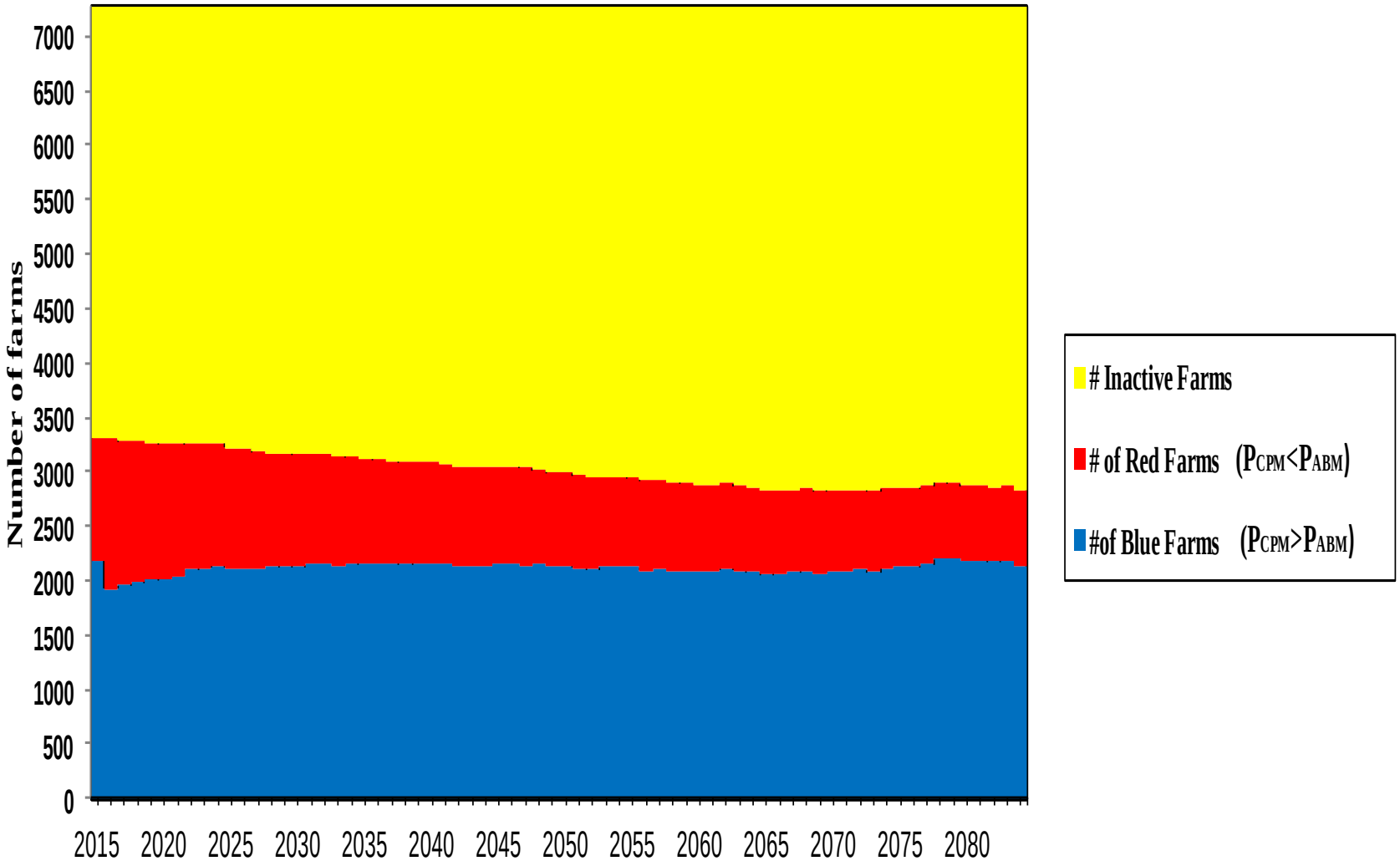
Results

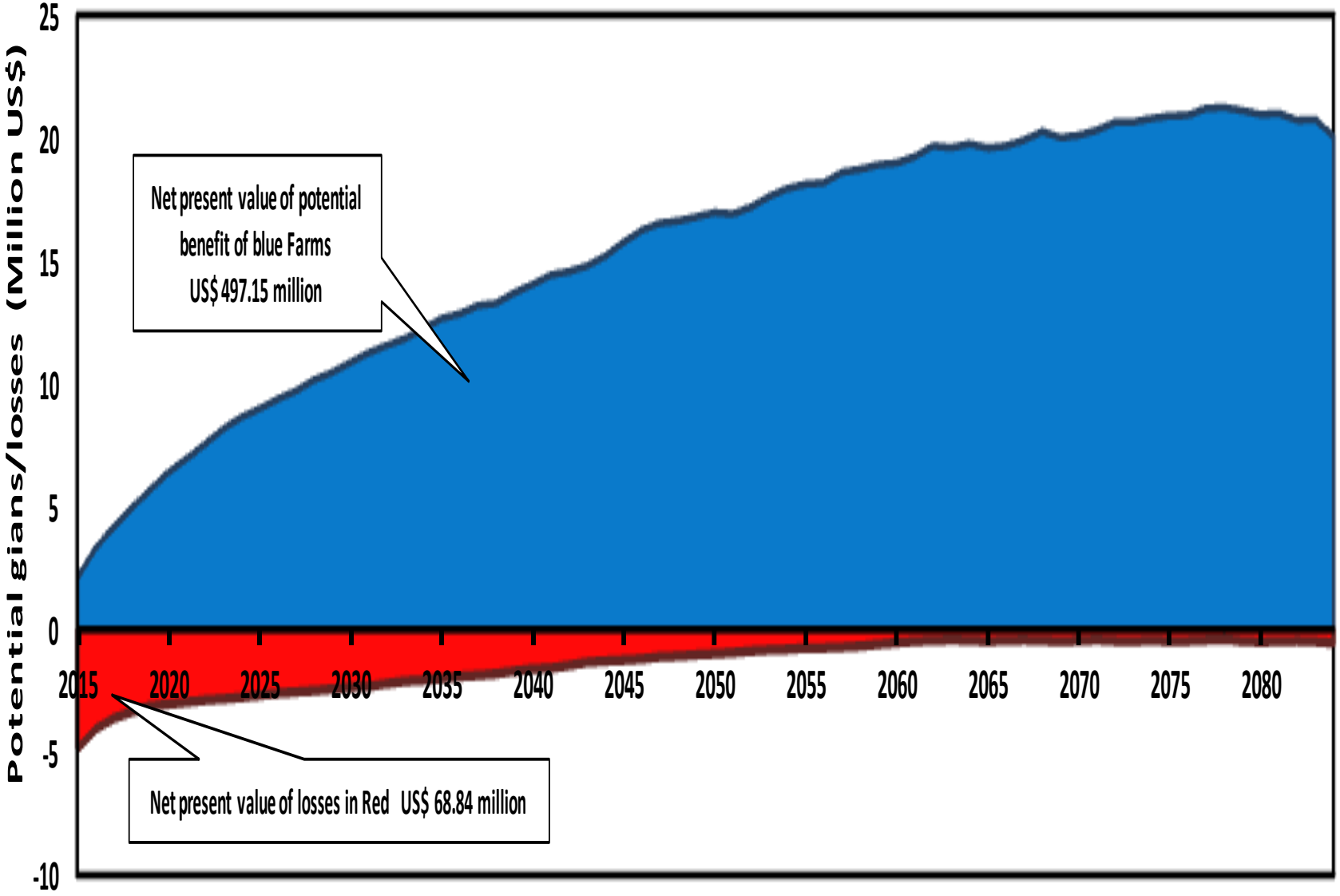

125
115
105
95
85
75
65
55
45
Profit (Million US$)
2014
2019
2024
2029
2034
2039
2044
2049
2054
2059
2064
2069
2074
2079
2084
CPM
ABM
BAU
Net Present Value of Potential Benefit from Cooperartion US$ 428.3 million



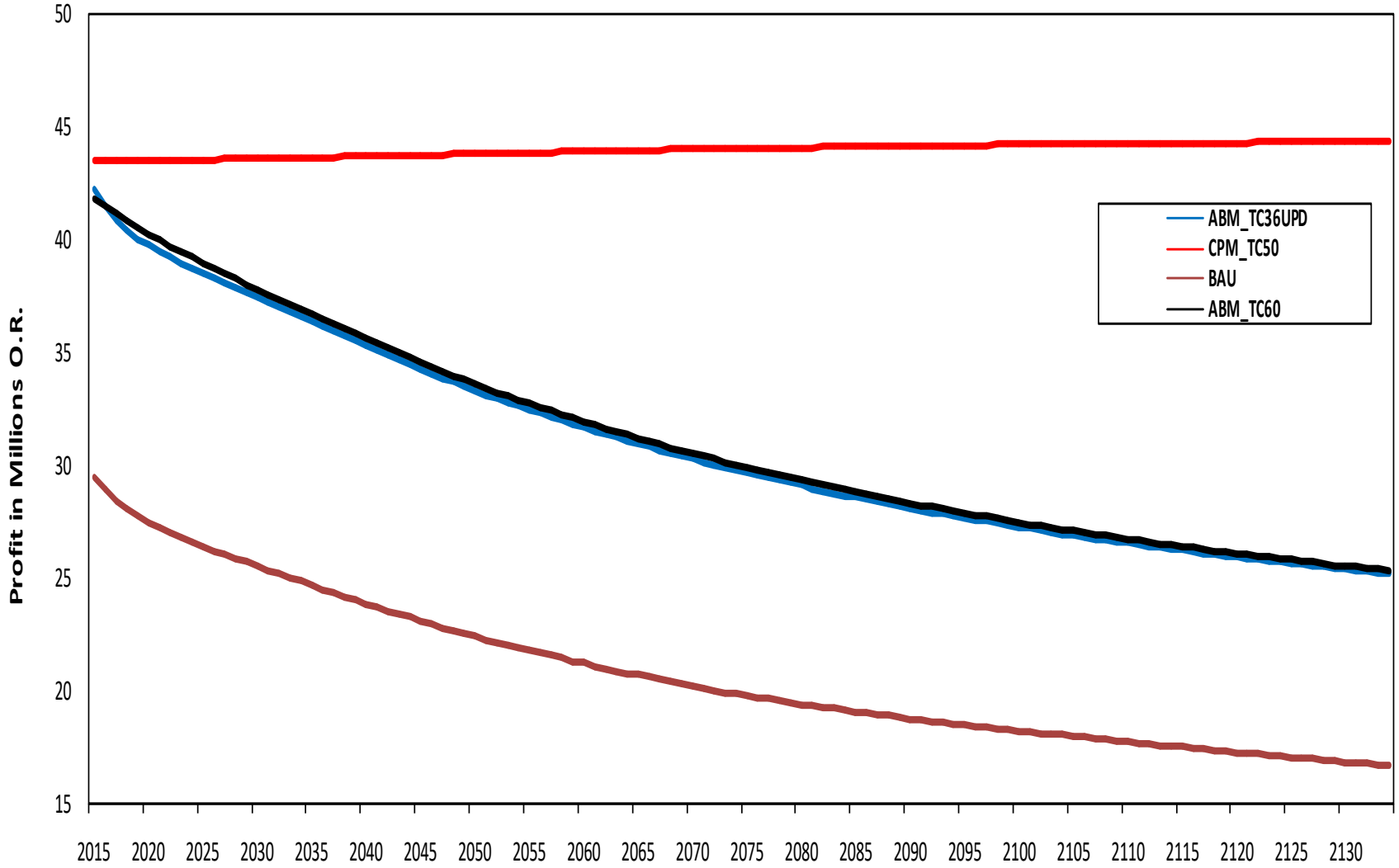

CPM
ABM
BAU
Totalcropped Area (Ha)
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
2014
2019
2024
2029
2034
2039
2044
2049
2054
2059
2064
2069
2074
2079
2084
5539
4561

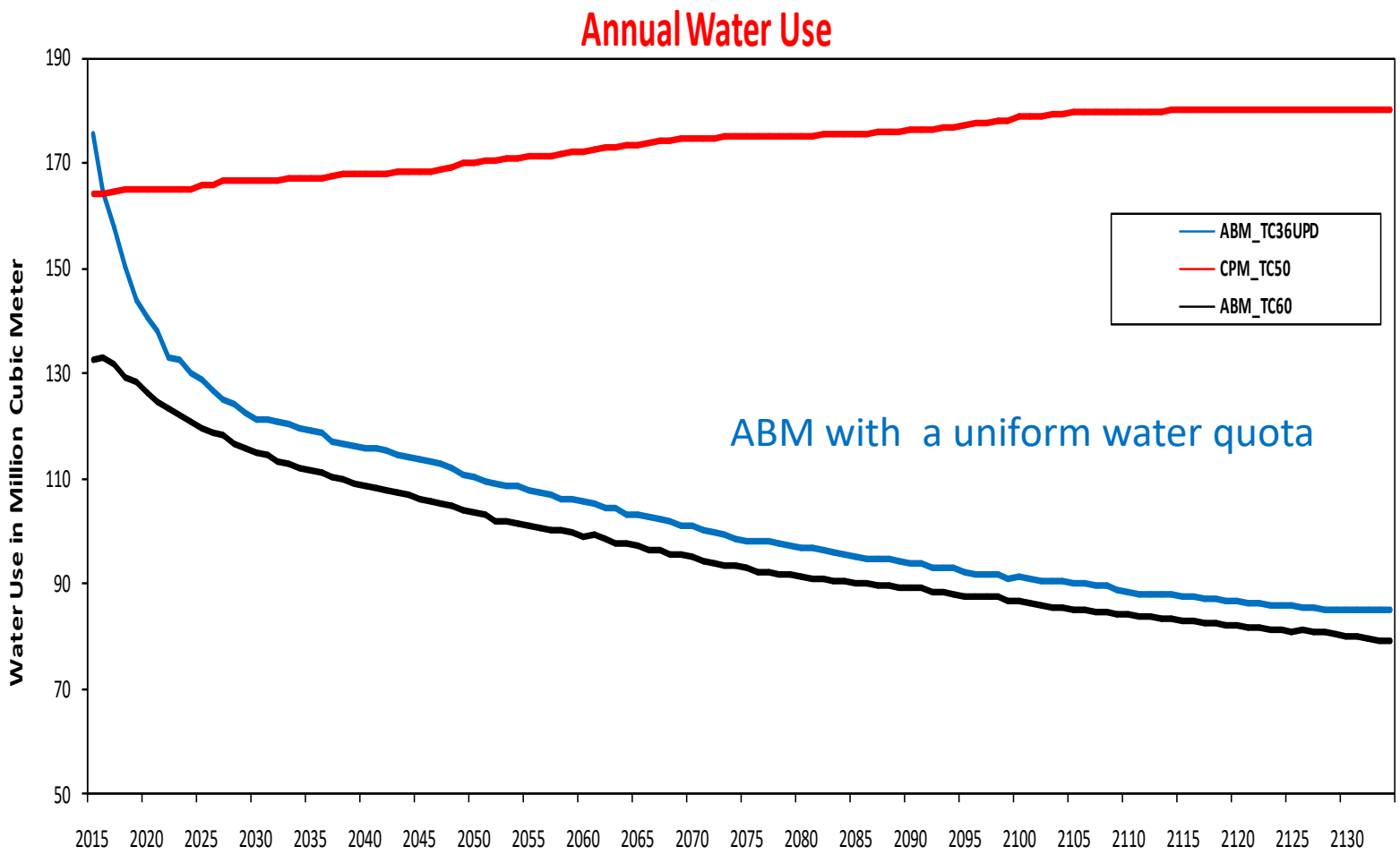

Percentage of land (%)
100
90
80
70
60
50
40
30
20
10
0
15.6
9.5
9.4
8.3
57.3
26.3
19.6
14.5
5.8
33.8
19.0
18.0
18.8
8.3
36.0
10.8
9.4
6.9
10.5
62.4
Current
BAU (year 70)
ABM (year 70)
CPM (year 70)
freshwater (<1.5gr/l)
low salinity (1.5-3gr/l)
moderate salinity (3-5gr/l)
high salinity (5-10gr/l)
very high salinity(>10gr/l)

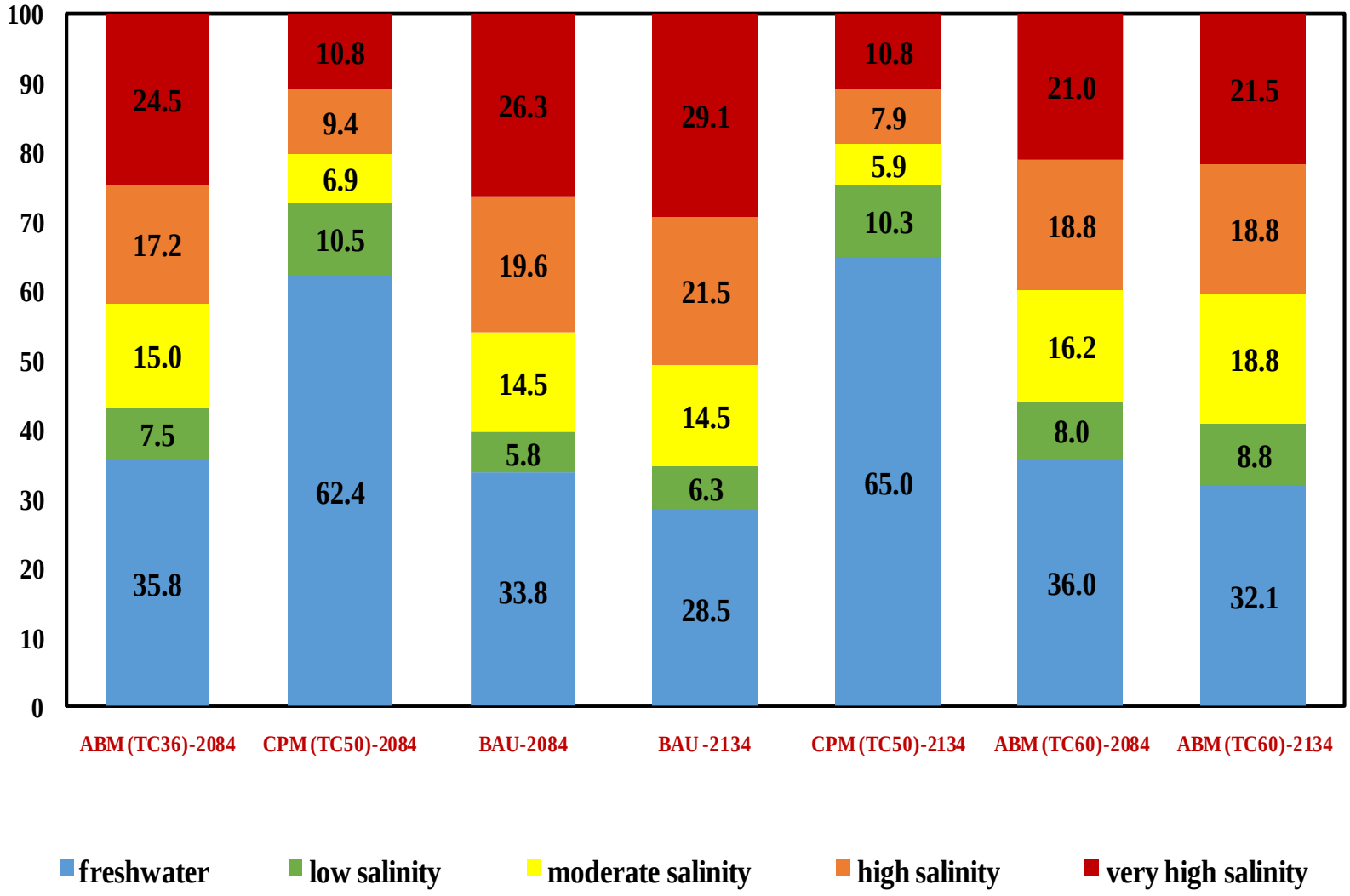

Number of farms
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
Inactive Farms
of Red Farms (PCPM<PABM)
#of Blue Farms (PCPM>PABM)


Potential gians/losses (Million US$)
25
20
15
10
5
0
-5
-10
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
Net present value of potential benefit of blue Farms US$ 497.15 million
Net present value of losses in Red US$ 68.84 million

Annual Profit






100
90
80
70
60
50
40
30
20
10
0
24.5
17.2
15.0
7.5
35.8
10.8
9.4
6.9
10.5
62.4
26.3
19.6
14.5
5.8
33.8
29.1
21.5
14.5
6.3
28.5
10.8
7.9
5.9
10.3
65.0
21.0
18.8
16.2
8.0
36.0
21.5
18.8
18.8
8.8
32.1
ABM (TC36)-2084
CPM (TC50)-2084
BAU-2084
BAU -2134
CPM (TC50)-2134
ABM (TC60)-2084
ABM (TC60)-2134
freshwater
low salinity
moderate salinity
high salinity
very high salinity

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Conclusions

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- Unmanaged aquifers are unsustainable
  - Business as usual will lead to increased salinization of the GW
  - 49.6% loss of cropped land towards end of century
- Benefit of a better Management = $1/2 Billion
- 50% of farmers will need to quit farming
  - Not a big problem in Oman as not depending on farming
- Smart metering is a first step
- GW Policies and regulations are required
  - Establish water rights but not sufficient
- Improving Marketing Ag. Products
- No reforms → No future for Ag. Sector