

Water Related R&D in Malaysia: An ASM Perspective

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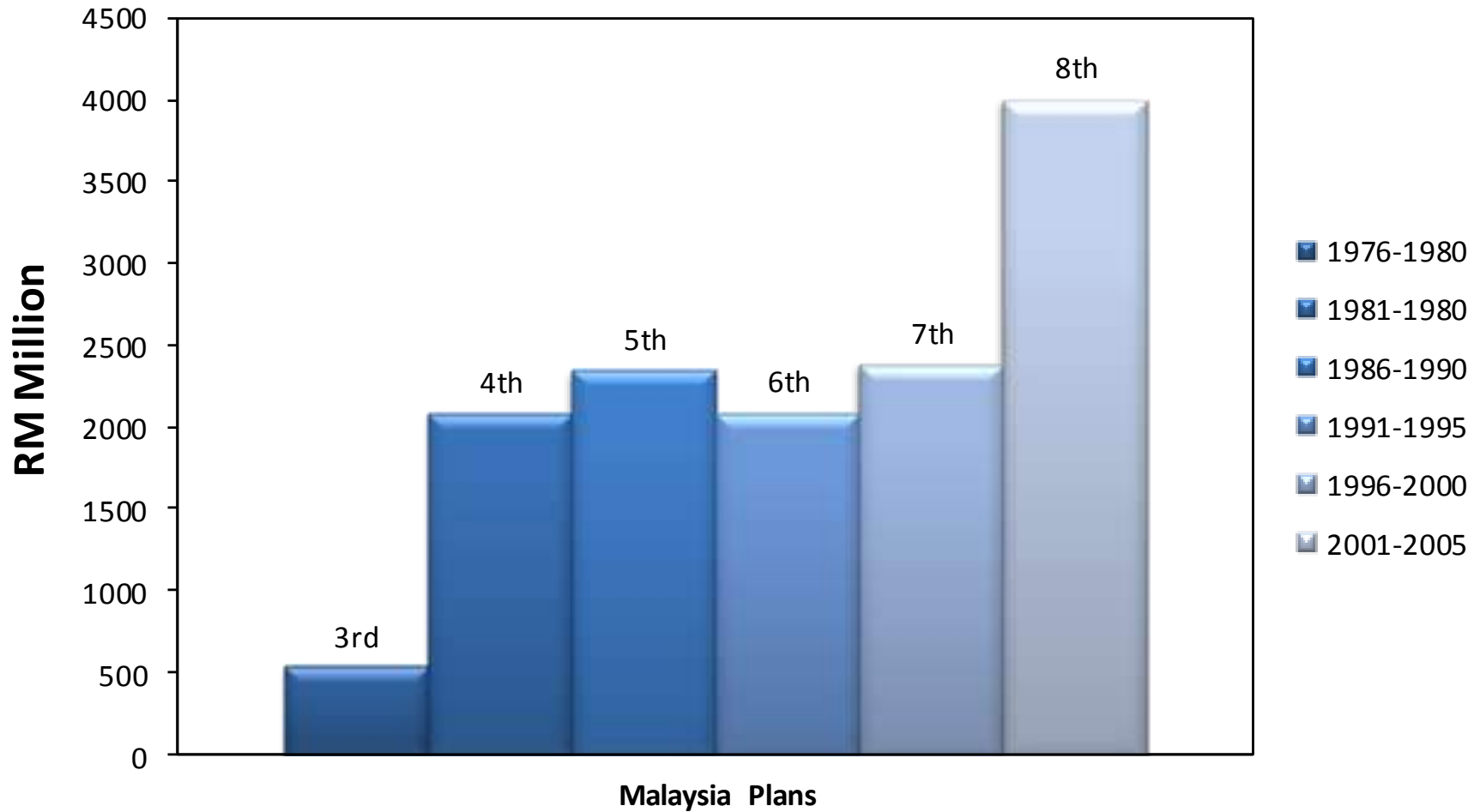


Outline

- Introduction
- Trend in Water R&D
- ASM Initiatives
- The way forwards

Introduction

Water Infrastructure Spending



Progress in water industry in the last decade and the way forward

8th Plan Period 2001-05

Stablization

- * Privatization and corporatization of state water authorities
- * Planning for restructuring of water services industry

9th Plan Period 2006-10

Consolidation

- * Operationalization of National Water Services Commisison (SPAN)
- * Enforcement of Water Services Industry Act (WSIA), 2008
- * Pengurusan Aset Air berhad (PAAB) takes over existing water assets from states at nagotiated values and is responsible for implementing water infrastructure devleopment
- * State water operators are asset-tight and focus on service provision

10th Plan Period 2011-15

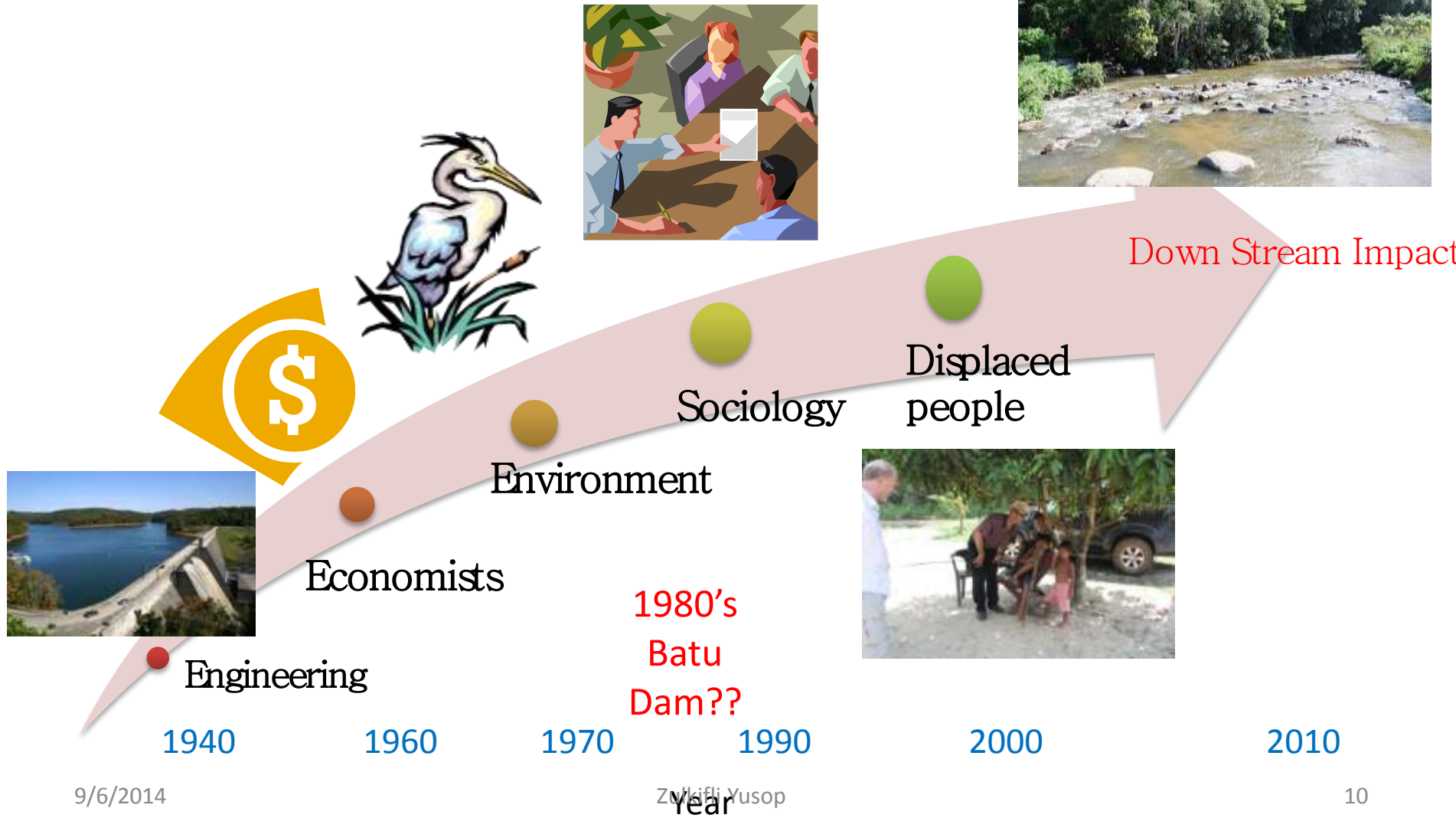
Moving towards efficiency in operations and management

- * Tariff-setting machanism to allow full cost recovery to be completely phased in by 2013
- * Integration of water supply and sewerage services
- * Initial efforts towards the introduction of integrated water and sewerage tariffs

Trend in Water and Wastewater Treatment Technology

Water issues getting increasingly complex

e.g Dam construction



Sewage treatment

Malaysian Scenario



1950's

1960's **Septic tank**

1970's **Imhoff tank**

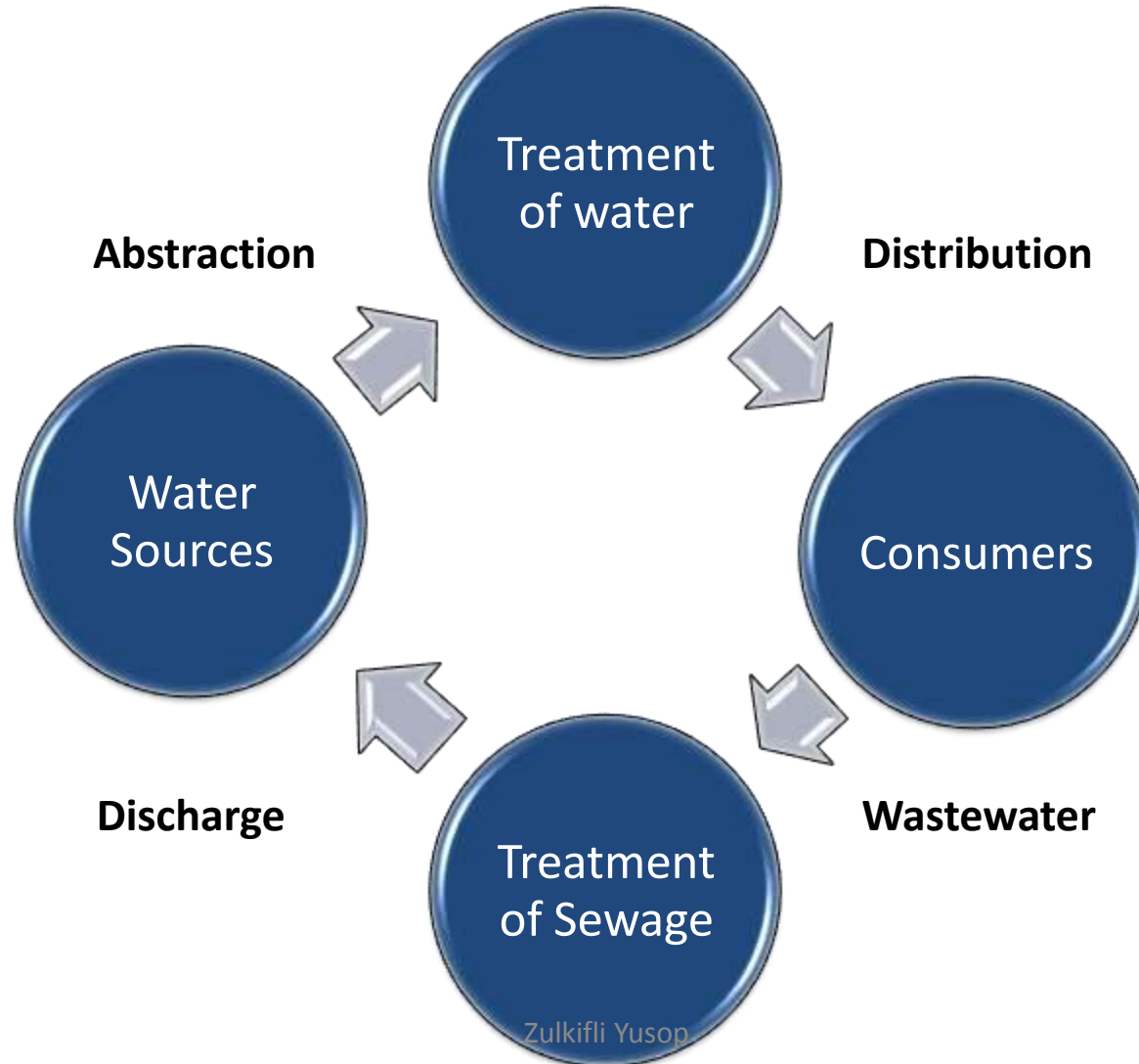
1980's **Oxidation pond/
Aerated lagoon**

1990's **Activated sludge/
Biological filters**

2000's **Fully mechanised
plant**

IWK, 2007

Integrated Concept– considering the whole value chain



Major trends of water pollution and its counter measures in developed countries

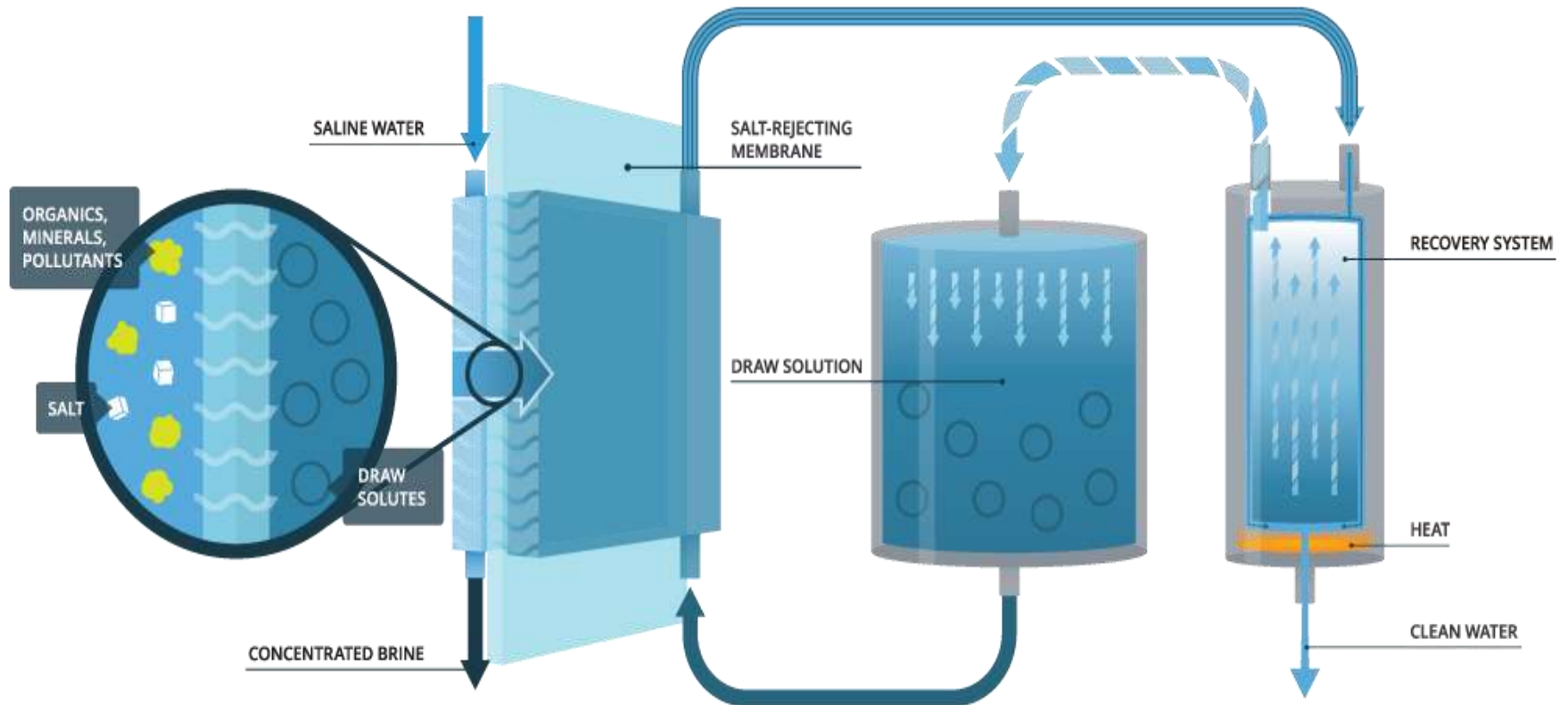
Era	Issues/Environmental impacts	Control measures
Pre-1900s	Pathogenic organisms	Sewer network
1910s	Organic pollutants from sewerage	Biological sewage treatment plant
1950s	Industrial waste, inorganics	Wastewater treatment on site before discharge to sewer
1960s	Other organics, pesticides, fat and grease, colour, solvents	Advanced biological and chemical treatments
1970s	Eutrophication	Nitrogen and phosphorus removal in sewage plant
1980s	Odor, taste, colour	Membrane technology, activated carbon
1990s	Green house gases	Biotechnology
2000s	Micro-pollutants, eco-hazards	Membrane technology
2010	Nutrient and energy recovery	Bioprocess

Examples of Emerging Technology

- Membrane Technology
 - More efficient materials
 - Forward osmosis
- Nutrient and Resources Recovery
 - Recovery vs removal
 - Urine separation
- Energy Recovery
 - Microbial fuel cells (MFCs), algal biofuel, gasification, pyrolysis, and anaerobic membrane bioreactor (AnMBR) for low strength wastewater

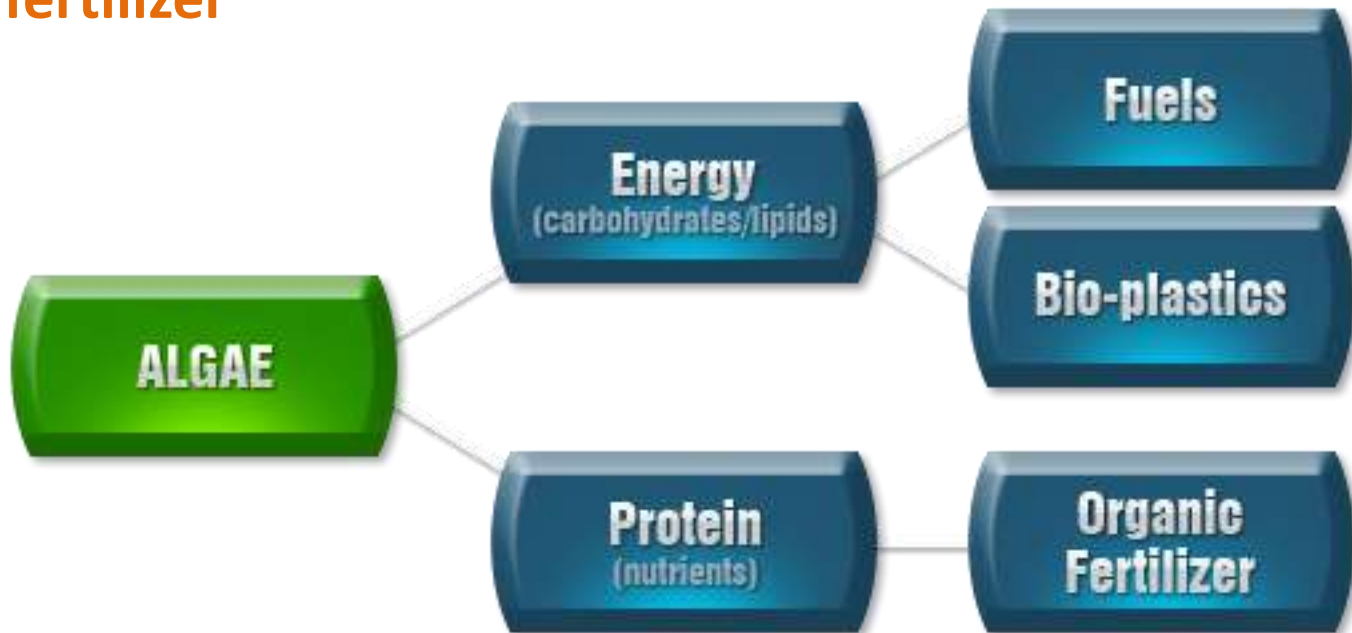
Forward Osmosis

- Lower Cost and Energy



The Algal Scientific Hypertrophic™ Water Treatment Process

- Remove organics and nutrients through **controlled specific-microalgae bloom** technology
- Biomass converted into **bio-energy**, **bio-plastics** and **fertilizer**

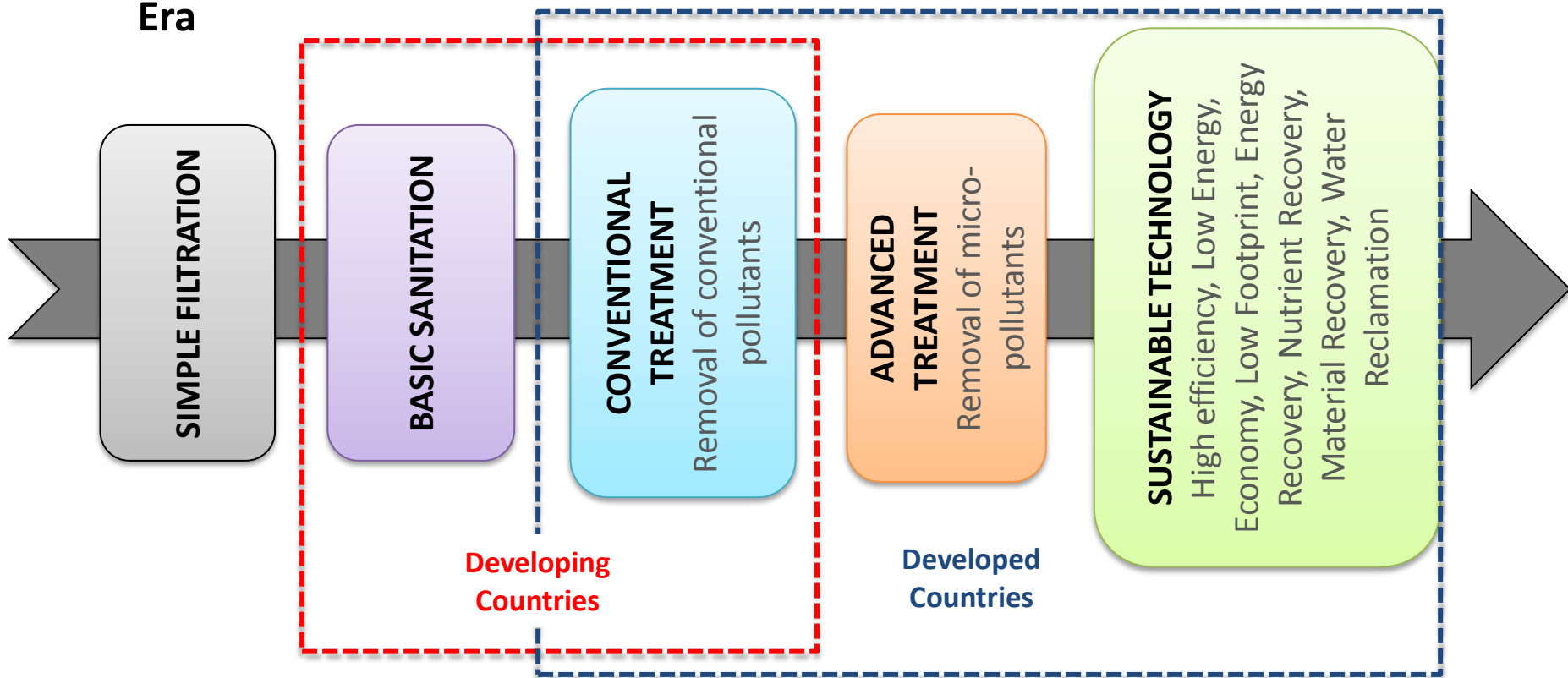


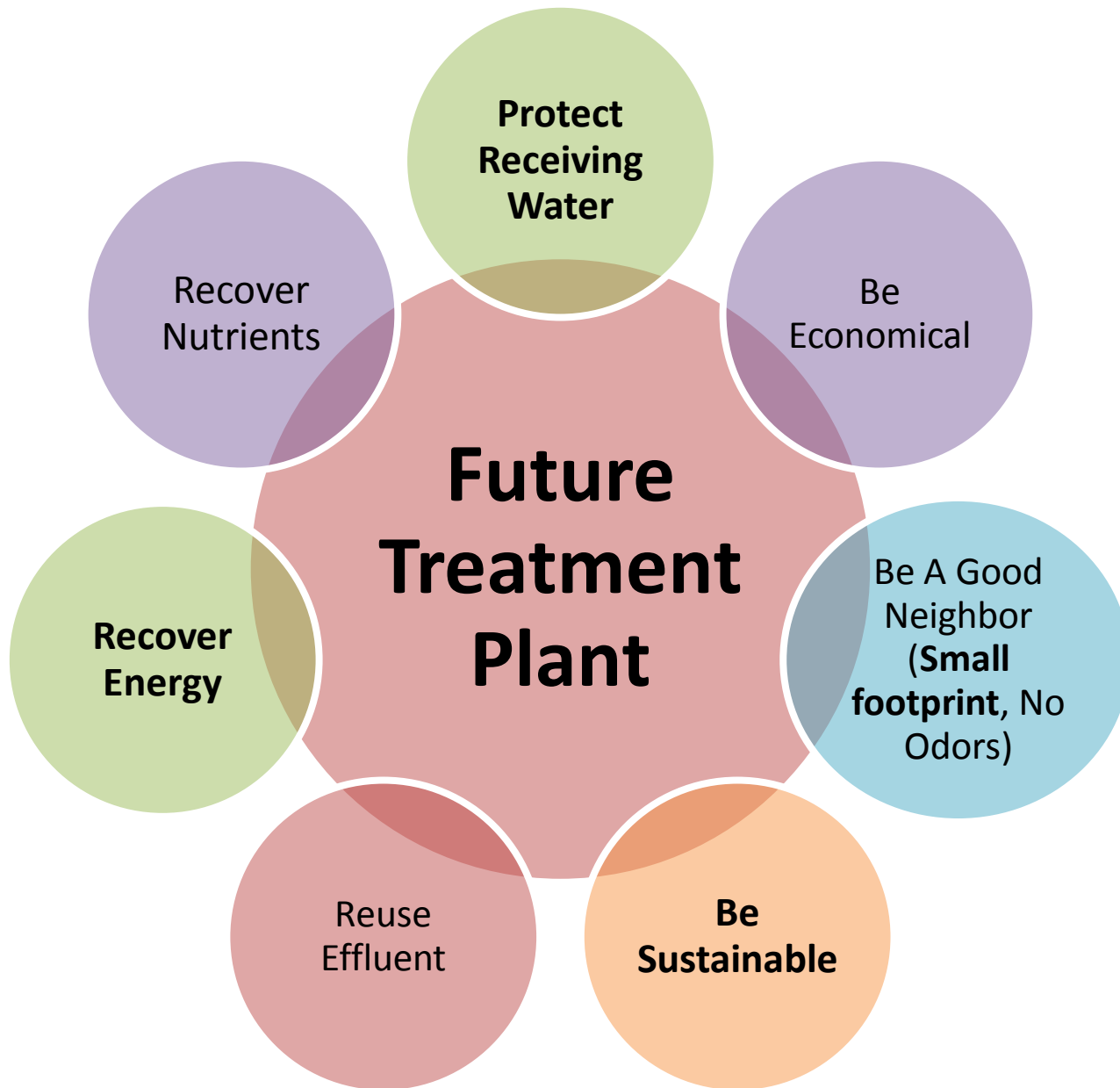
Evolution of Treatment Technologies

in Modern Era

Early Modern
Era

The Future





Current Main Criteria

Authority
requirements

Low **cost**



R&D FUNDING

FRGS covers six areas

1. Pure Science
2. Applied Science
3. Social Sciences and Literature
4. Medical Science, Technology and Engineering
5. Natural Science
6. National Heritage

MoEM - LRGS

1. Global warming
2. Infectious disease
3. Tropical medicine
4. Energy and **water security**
5. Adequacy of food
6. Advanced manufacturing and added-value
7. Information and communication technology (ICT)

Research priority areas for MOSTI ScienceFund, TechnoFund, and InnoFund:

1. Life Sciences
2. Comp Sci. and Info. and Communication Tech (ICT)
3. Agriculture Sciences/ Agricultural Engineering
4. Environmental Sciences
5. Advanced Materials Science
6. Chemical Sciences
7. Physical and Mathematical Sciences
8. Engineering
9. Medical and Health Sciences
10. Social Sciences and Humanities.

MOSTI Flagship Program. Must have an impact on the development of STI and aligned with the New Economic Model (NEM). A top-down approach, and the National Science and Research Council (NSRC) sets the following research priorities

1. Biodiversity
2. Cyber security
3. Energy Security
4. Environment and Climate Change
5. Food Security
6. Medical and Healthcare
7. Plantation Crops and Commodities
8. Transport and Urbanization
9. **Water Security** (Sustainable sources and processing, treatment & distribution of water)

ASM INITIATIVES

- **ASM WEHABE Committee on Water** (preceded earlier by the ASM Water Committee since 2008)
- The overall goal “**to manage water resources (both surface and ground water) in a sustainable manner and in accordance with IWRM principles and practices**”.
- Realization of the longer term twin STI opportunities identified under the **Mega Science Framework Study for Sustained National Development for the Water Sector (2010 – 2050)**, emphasizing on wealth creation and for sustaining the resources.
- Complements work done by others towards achieving the goals and objectives of the **National Water Resources Policy (2012)**.
- **Various task forces:**
 - 1) Integrated Lake Basin Management
 - 2) Ground water
 - 3) Water Demand Management
 - 4) Water Supply and Wastewater management
 - 5) Integrated River Basin Management
 - 6) **National R&D Agenda for Water**,
 - 7) climate Change and Water Resources,
 - 8) S&T Awareness, International Networking,
 - 9) Water for Agriculture,
 - 10) Water Policy

MEGA SCIENCE FRAMEWORK STUDY —WATER SECTOR

Two types of STI

- i. STI that sustain the existing opportunity –
Sustaining resources
- ii. STI that can create New Wealth and Wellness
 - Situational Analysis identified 70 STIs
 - Zoomed to 21 using Return – Risk Analysis

ASM Study on Mega Science Framework for Water

Creating new wealth

1. Eco-tourism around high ecological value sites
2. Urban water-based tourism
3. Market and export high quality water
4. Clean water for the aquaculture industry
5. Malaysian brand of domestic water purification units
6. World leading tropical aquatic research and education
7. Knowledge export
8. Tapping urban water
9. Rainwater harvesting
10. Zero pollutant discharge

ASM Study on Mega Science Framework for Water

Sustaining the resources

1. Exploit groundwater resource up to 20% of the
2. Improve flood forecasting and mitigation
3. Reform water education system
4. Improve ecosystem protection from point and NPS pollution
5. Clean-up and rehabilitate waterways in highly visible locations
6. Improve irrigation water use efficiency
7. Ecosystem services values
8. Advanced water and wastewater treatment
9. Wetlands ecosystem repair/restoration
10. Water management planning to improve resilience with uncertain future

5.1.4 Tapping Urban Runoff

(Return- sc 7.7 Risk sc 4.2)

- Concept
 - Impoundment of urban runoff using man-made structure, e.g. barrage
- Benefit
 - Create new source of water
 - Promote basin scale river/water protection
 - Create eco-tourism opportunity
 - Alternative to costly and sensitive water transfer project Enhance life style and awareness

Doing it right

City runoff —

Doing it wrong

Marina Barrage



Iconic Water Project
Water Supply
Tourism

Where: Inkandar Malaysia,
Putrajaya



Urban runoff flows into
water is naturally treated, infiltrates to feed groundwater,
and provides wildlife habitat. What a great idea!

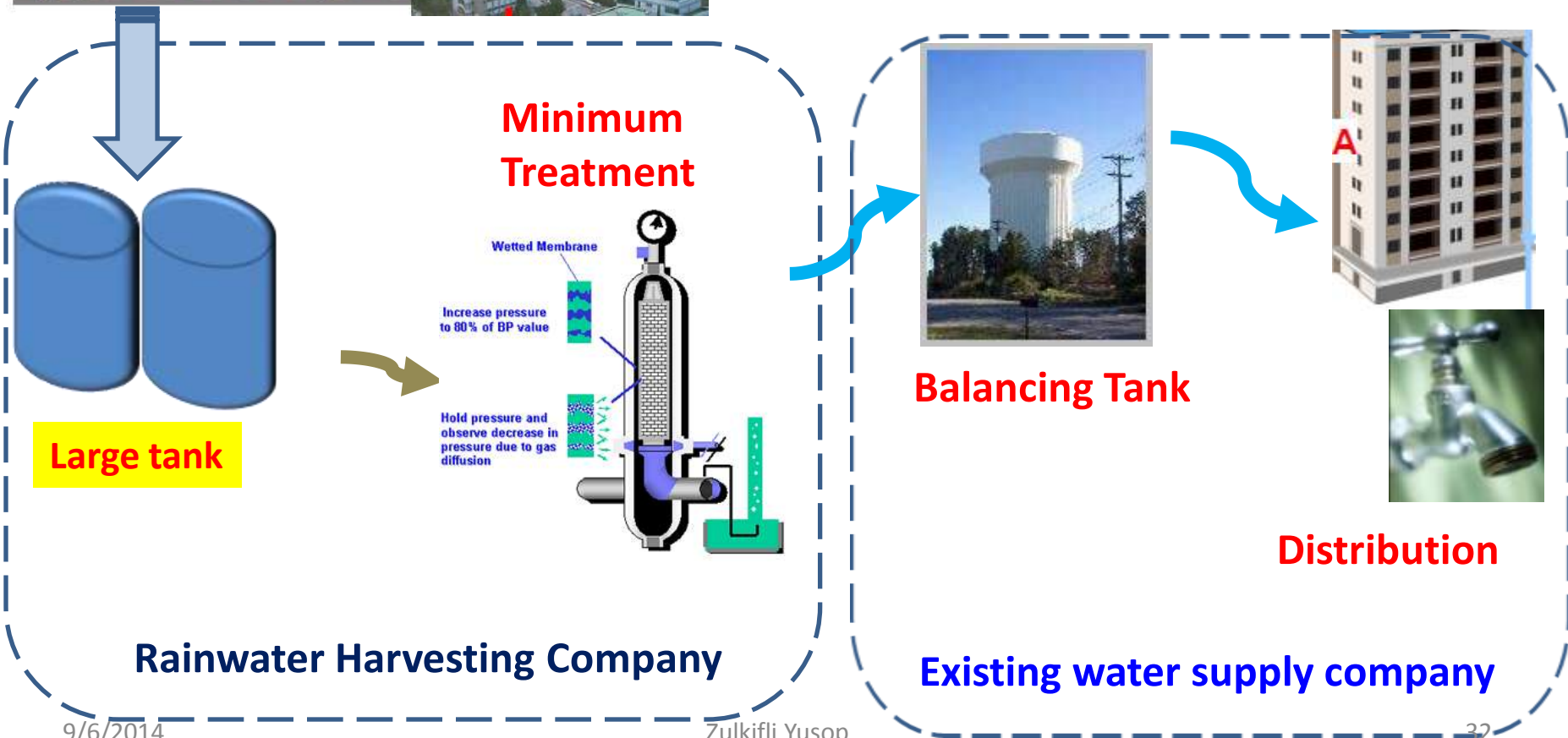
5.1.5 Large Scale Rainwater Harvesting

Return- sc 7.4 Risk sc 4.3

- Concept
 - Collection of rainwater from roof in a big scale for enhancing water supply and minimise flash flood
- Benefit
 - Minimise dependent on tap water
 - Regulate excess water and reduce flash flood
 - Prolong new water resource structure and the saving can be used for more urgent project



**Residential /Commercial Area
of ~ 30 thousands houses**



5.2.4 Improve Ecosystem Protection from Point and Non-point Pollution

Description of the Opportunity

- Ecosystem protection/conservation in Malaysia
 - ✓ focusing towards biodiversity (endangered plant and animal species)
 - ✓ lack of focus on the protection of ecosystem services

- Ecosystem protection implementation
 - ✓ identifying spatial priorities for conservation action (i.e. area selection) and
 - ✓ the development of an implementation strategy with the involvement and collaboration of the stakeholder, i.e., the agencies who will take implementation of the plan forward.
 - ✓ Ecosystem services protection assessment and planning - regulatory, provisioning, supporting, and cultural

Benchmarking Against Similar Initiatives

- **The New York City drinking water supply system**
 - ✓ the largest unfiltered water supply in the US
 - ✓ Provides 1.2 billion gallons of high quality drinking water to one-half the population of New York State every day
 - ✓ cost of \$1 billion – avoid filtration cost of \$8.0 - \$10.0 billion to construct the facility and \$1.0 million/day to operate and maintain the filtration plant.

- **The Great Barrier Reef in Australia**
 - ✓ establishment of new legislation to non-point discharge
 - ✓ multi zoning of the marine park with restricted use of each zone
 - ✓ Extensive ecosystem science provided the foundation for the development detailed code of practice for tourism operators to minimise the ecosystem damage, enabling a sustainable eco-tourism industry.



**An Ounce of Protection
vs. a Pound of Cure**



ASM Initiatives

Study on the Current Status
and Needs Assessment of
Water Resources Research in
Malaysia

Rank	University	ENGINEERING	SCIENCE	SOCIAL
1	Universiti Teknologi Malaysia	<div><div></div></div> 15	<div><div></div></div> 36	0
2	Universiti Malaysia Terengganu	<div><div></div></div> 8	<div><div></div></div> 29	<div><div></div></div> 4
3	Universiti Putra Malaysia	<div><div></div></div> 7	<div><div></div></div> 19	<div><div></div></div> 3
4	Universiti Sains Malaysia	<div><div></div></div> 8	<div><div></div></div> 16	<div><div></div></div> 4
5	Universiti Teknologi MARA	<div><div></div></div> 3	<div><div></div></div> 16	<div><div></div></div> 5
6	Universiti Malaya	<div><div></div></div> 4	<div><div></div></div> 12	<div><div></div></div> 1
7	Universiti Malaysia Sabah	<div><div></div></div> 2	<div><div></div></div> 7	<div><div></div></div> 3
8	Universiti Tun Hussein Onn Malaysia	<div><div></div></div> 5	<div><div></div></div> 6	0
9	Universiti Malaysia Perlis	<div><div></div></div> 2	<div><div></div></div> 8	0
10	Universiti Malaysia Pahang	<div><div></div></div> 2	<div><div></div></div> 4	0
11	Universiti Kebangsaan Malaysia	<div><div></div></div> 2	<div><div></div></div> 2	<div><div></div></div> 1
12	Universiti Malaysia Sarawak	0	<div><div></div></div> 4	0
13	Universiti Pendidikan Sultan Idris	0	<div><div></div></div> 4	0
14	Universiti Teknikal Malaysia Melaka	<div><div></div></div> 3	0	0
15	Universiti Pertahanan Nasional Malaysia	<div><div></div></div> 1	<div><div></div></div> 1	0
16	Universiti Sultan Zainal Abidin	0	<div><div></div></div> 1	0
17	Universiti Sains Islam Malaysia	<div><div></div></div> 1	0	0
18	Universiti Malaysia Kelantan	0	<div><div></div></div> 1	0
9/6/2014 TOTAL		63	166	21

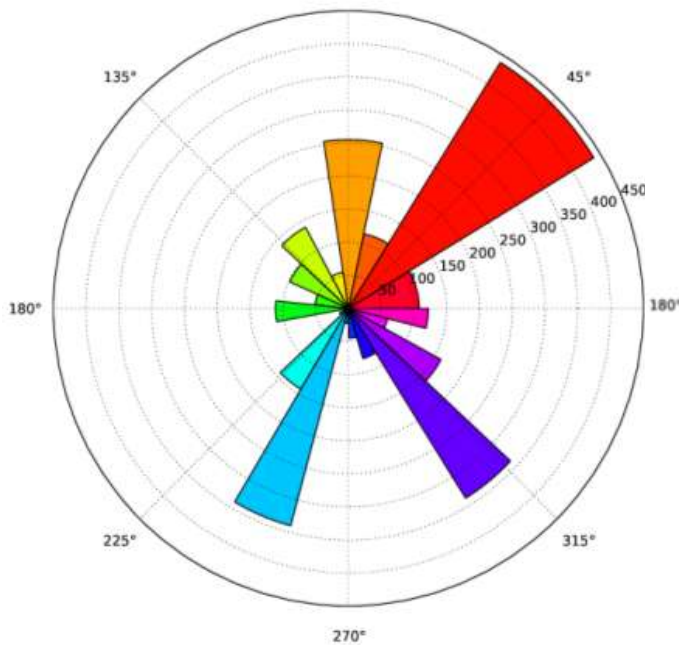
MoE grants distribution according to research discipline

Basic Statistics

- 489 from ISI, 2027 from Scopus
- Publication year from 1964 – 2012
- 5277 unique authors, 814 unique institutions
- (Publication, citation) vs num authors follow hyperbolic trend
 - 3500 authors with only ONE publication
 - 1800 authors with ZERO citation
- Serious positive skewness

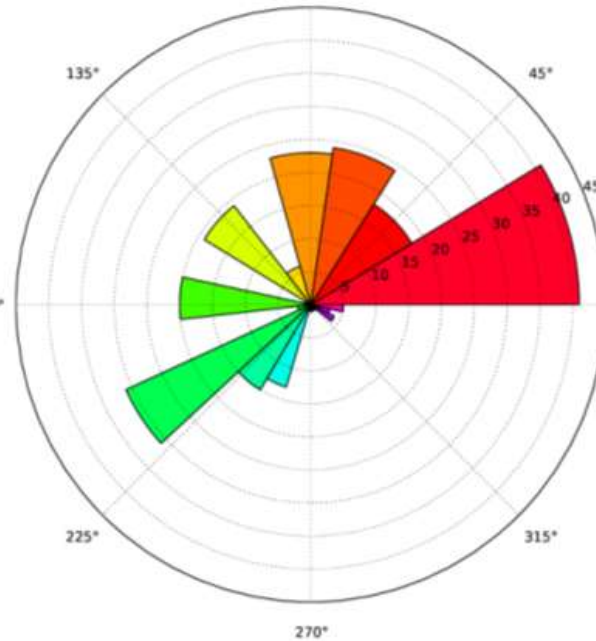
Authors Analysis

Top 20 Authors
(Publications)



Degree proportional to
publications, arc
proportional to citations

Top 20 Authors
(Citations)

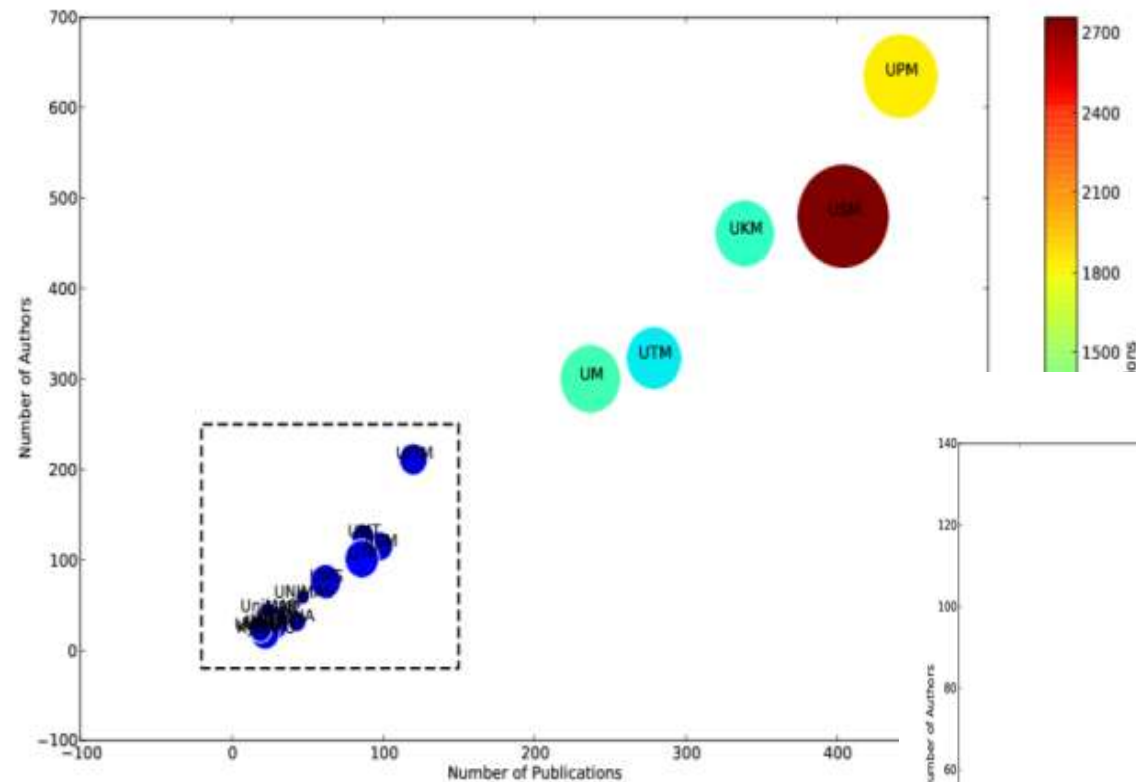


Degree proportional to
citations, arc
proportional to
publications

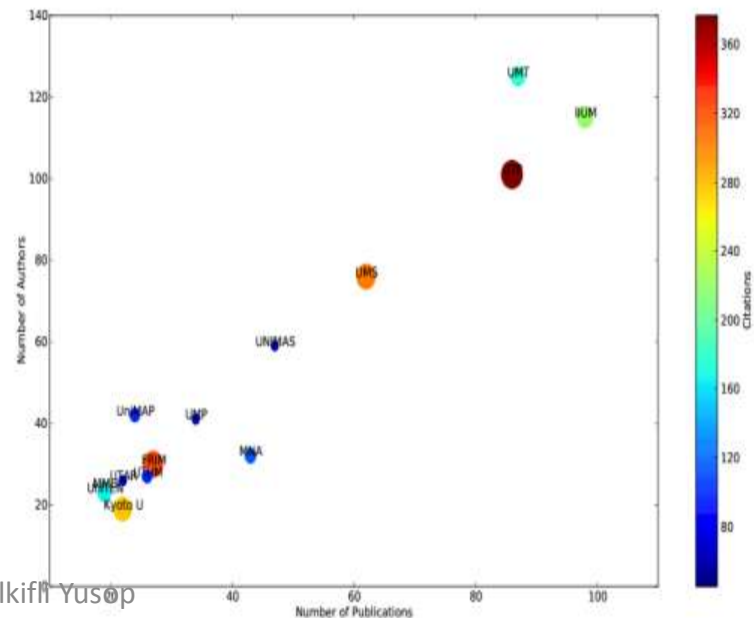
- Shift in ranking (top publications vs top citations)
- High publications tend to yield high citations (12/20)
- 10/20 top citations < 5 publications

Institutions Analysis

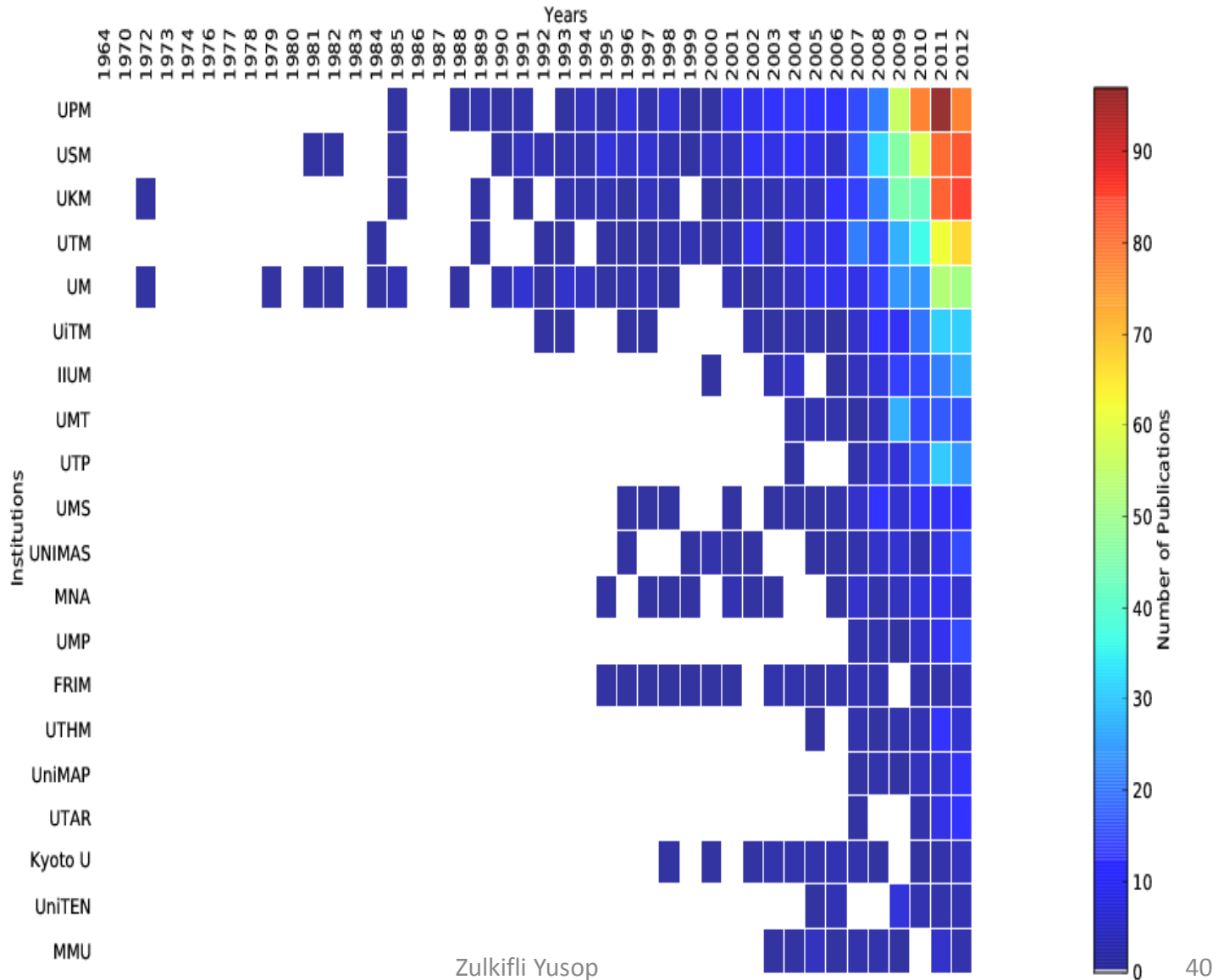
- Top 5 RUs
- Gap between RUs & non-RUs
- Generally high number of authors = high number of publications



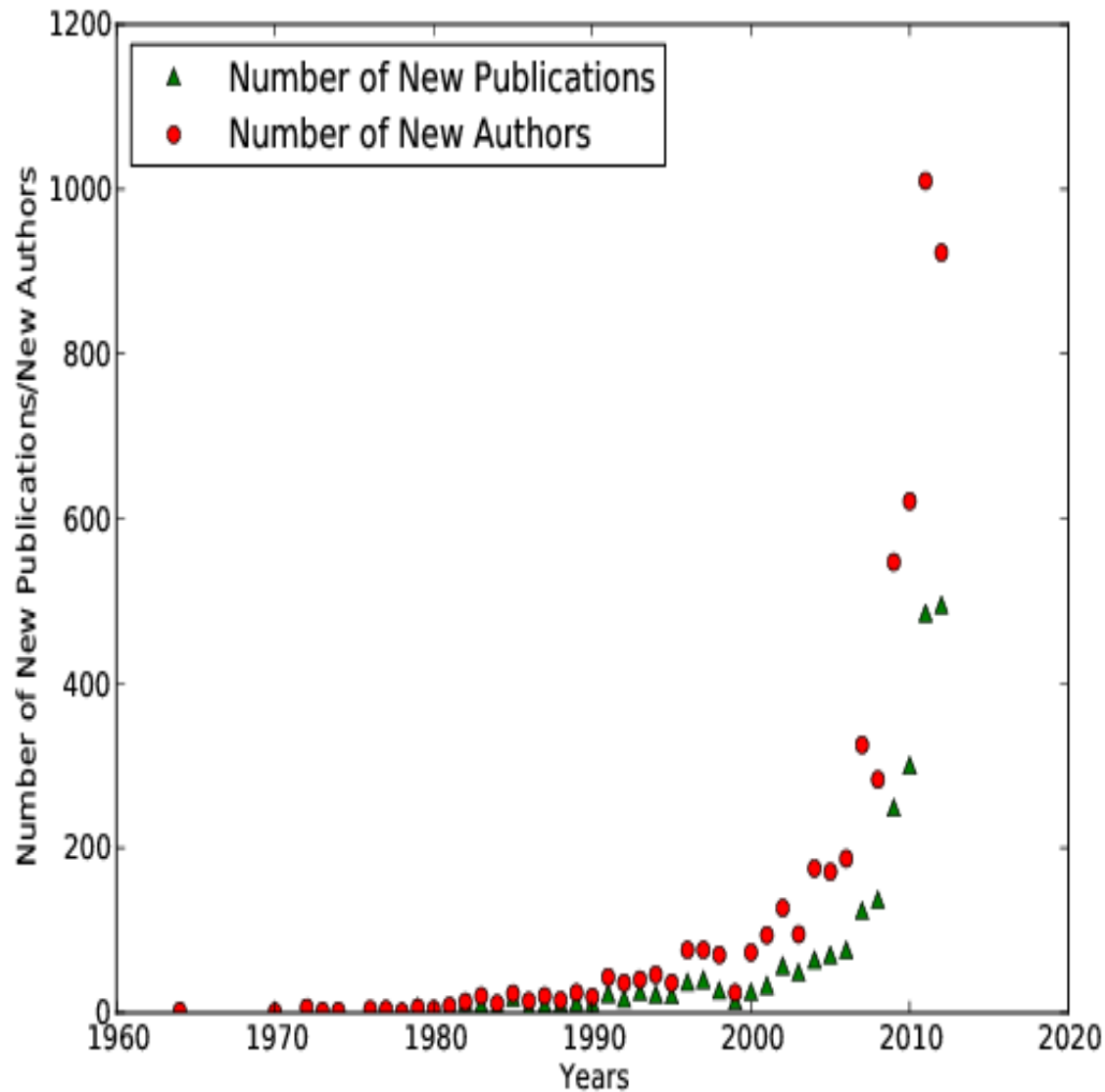
- Number of authors vs number of publications
- Warmer color = higher citations



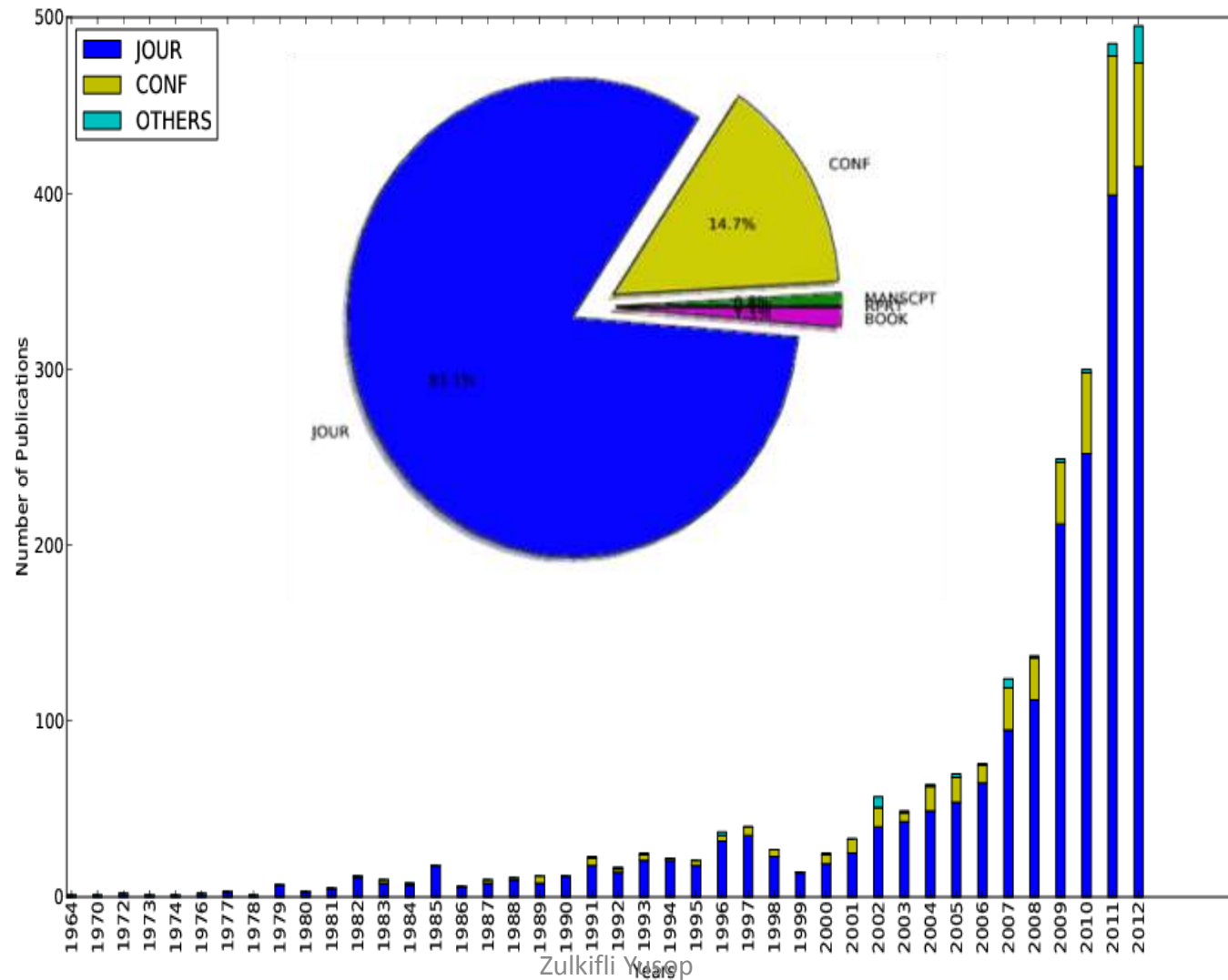
Institutional Analysis



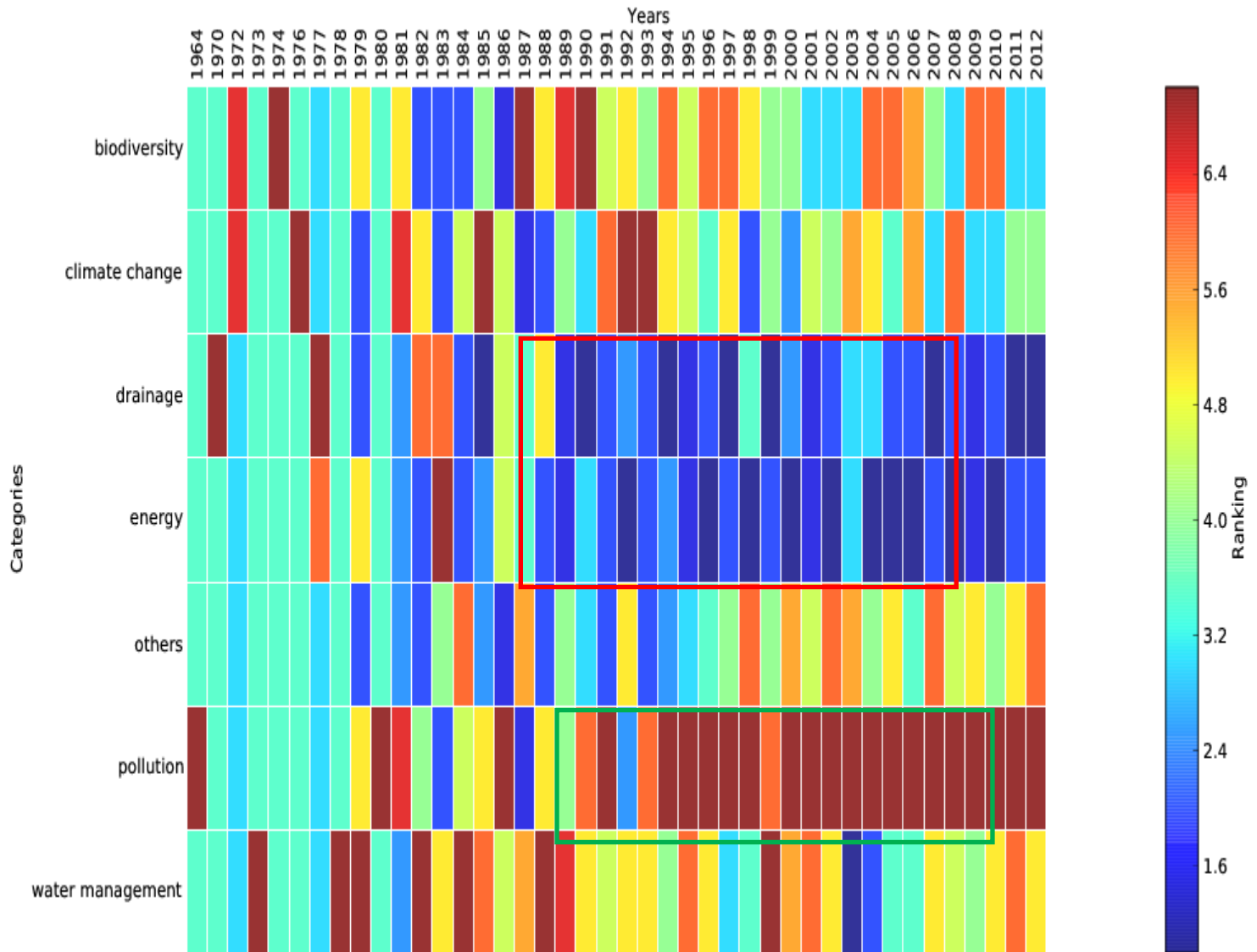
New Article – New Author Increment



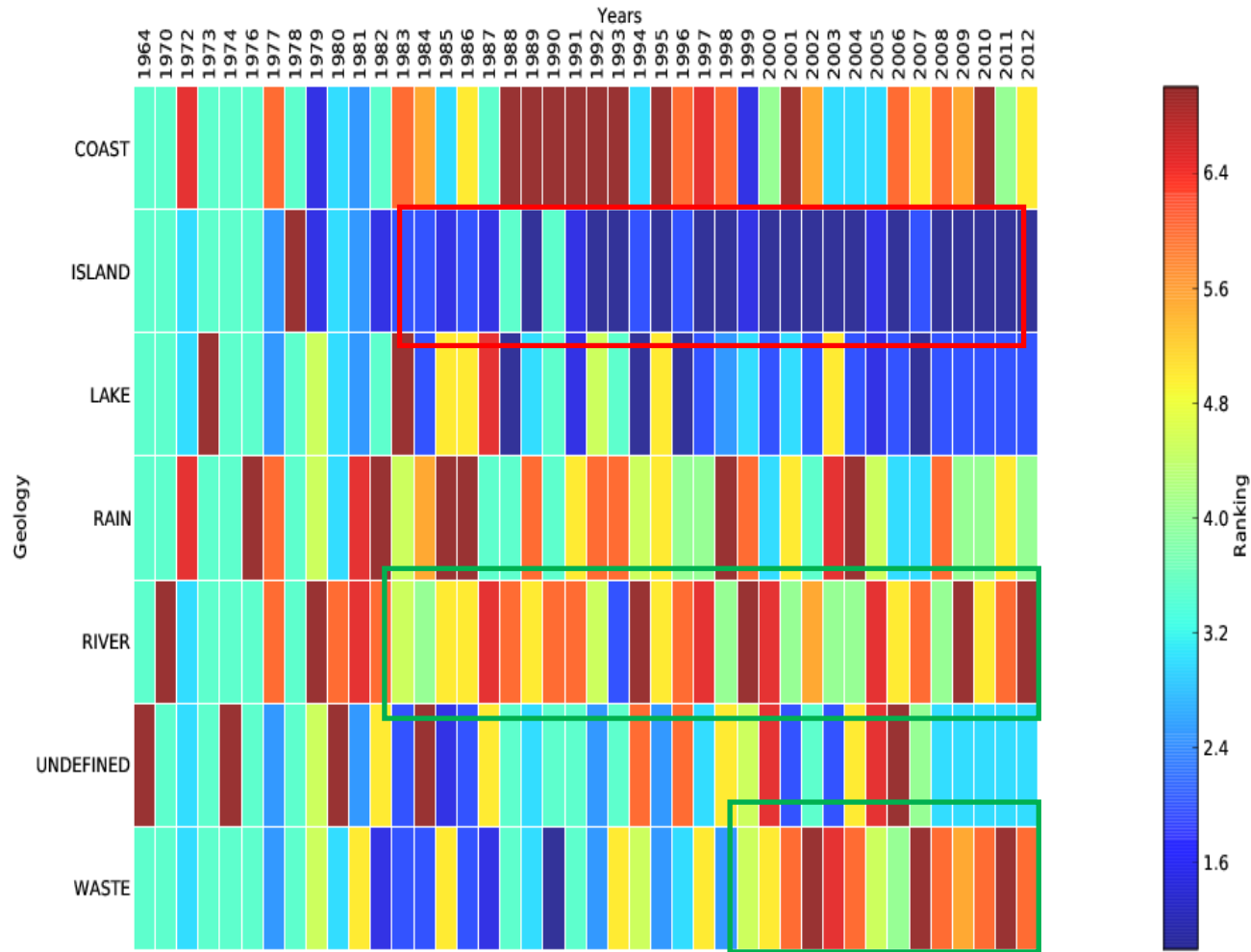
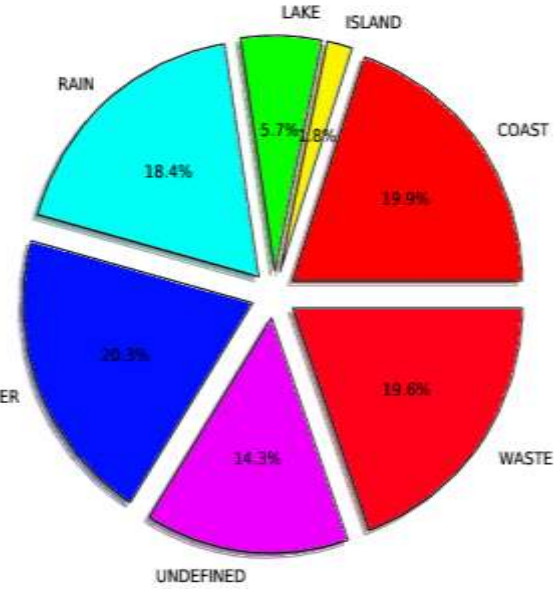
Articles Analysis



Categorization



Geological Classification

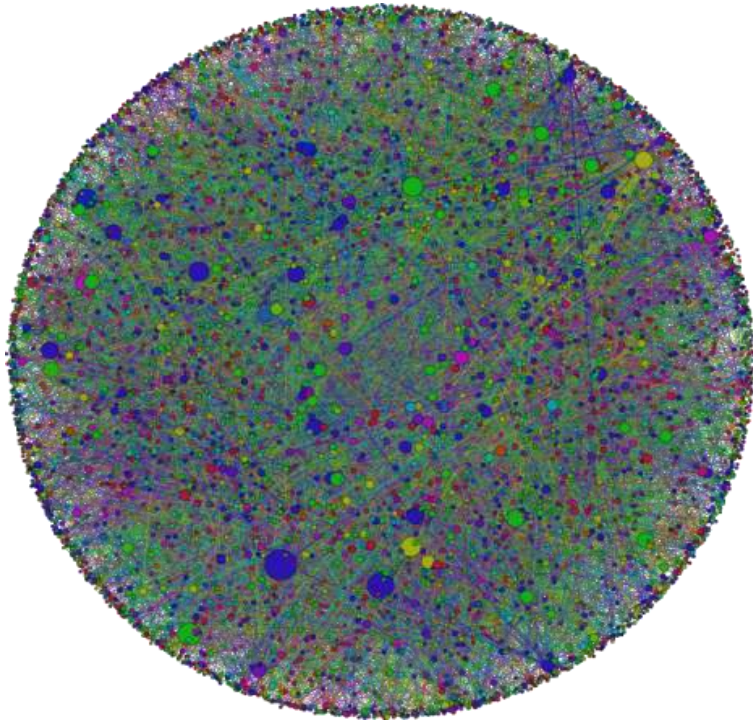


Expertise

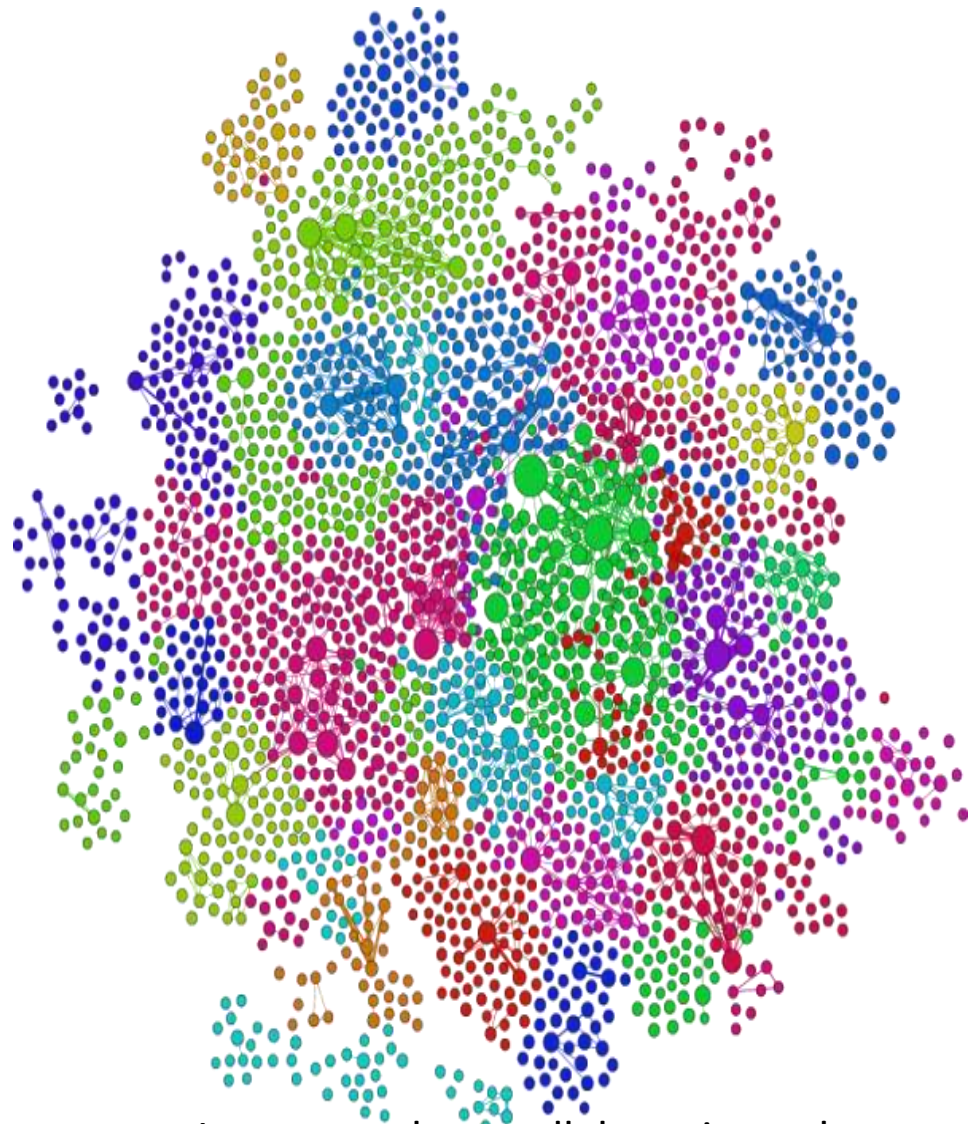
Categories	Institutions		
	1st	2nd	3rd
Water management	UKM	UPM	UTM
Climate change	UKM	UTM	USM
Pollution	UPM	USM	UKM
Biodiversity	UPM	UKM	USM
Drainage	UPM	UM	USM
Energy	UTP	UKM	UPM
Others	USM	UTM	UPM

Categories	Authors		
	1st	2nd	3rd
Water management	Mokhtar, M. [UKM]	Manan, Z.A. [UTM]	Aris, A.Z. [UMS; UPM]
Climate change	Jemain, A.A. [UKM]	Deni, S.M. [UITM]	Toriman, M.E. [UKM]
Pollution*	Yap, C.K. [UPM]	Aziz, H.A. [USM]	Ismail, A. [UPM]
Biodiversity*	Kamaruzzaman, B.Y. [IIUM; UMT]	Aris, A.Z. [UMS; UPM]	Ahmad, Z. [MNA; UKM]
Drainage	Lee, T.S. [UPM]	Amin, M.S.M. [UPM]	Rowshon, M.K. [UPM]
Energy*	Choy, F.K. [TNB]	Cheong, B. [Schlumberger]	Daungkaew, S. [Schlumberger]
Others	Azamathulla, H.M. [USM]	Marghany, M. [UTM]	Ismail, A.F. [UTM]

Authors Network



Authors collaboration network



- Largest authors collaboration sub-network
- Colors = communities
- Top 50 (collaborations) are in this sub-network

Authors Collaborations

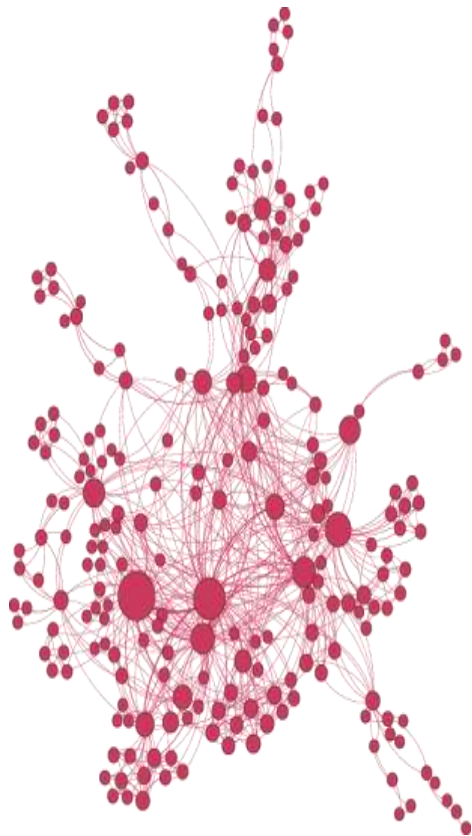
Rank	Author	Intra	Inter	Inter Inst
1	Yusop, Z. [UTM]	11	26	10
2	Juahir, H. [UPM]	20	32	12
3	Salim, M.R. [UTM]	19	14	8
4	Mokhtar, M. [UKM]	59	28	11
5	Ujang, Z. [UTM]	25	31	27

- Important personnel “connecting” different communities

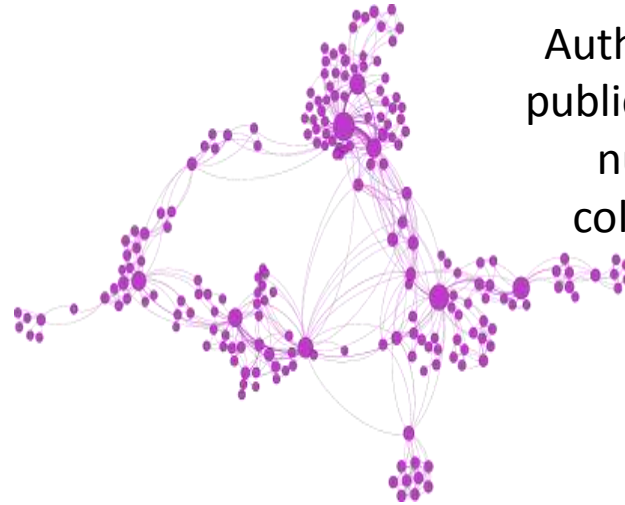
Rank	Author	Intra	Inter	Inter Inst
1	Mokhtar, M. [UKM]	59	28	11
2	Toriman, M.E. [UKM]	64	6	3
3	Aziz, N.A.A. [UKM]	40	3	2
4	Gasim, M.B. [UKM]	36	8	4
5	Juahir, H. [UPM]	20	32	12

- Important personnel in their own communities

Network Density



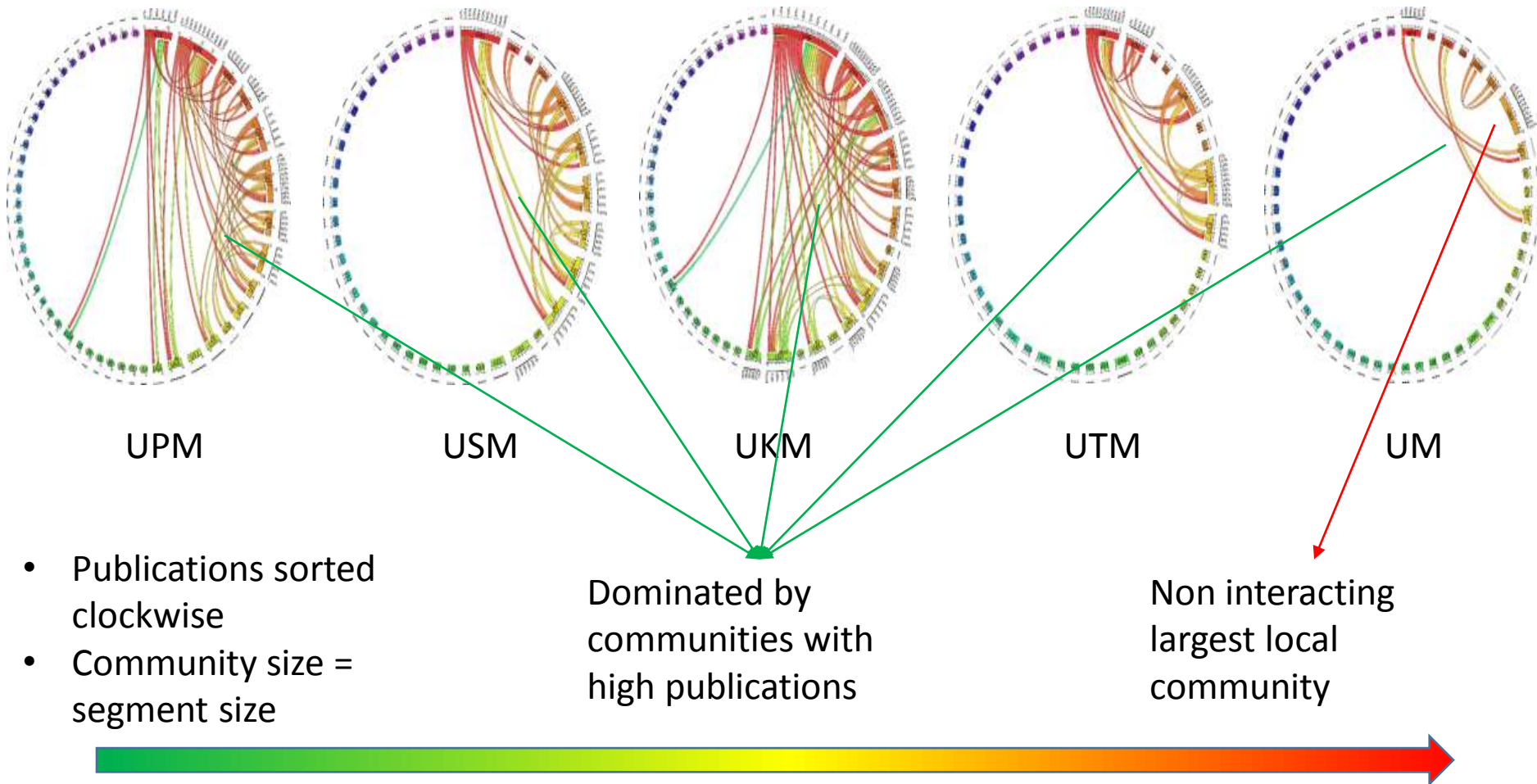
Author with top eigenvector
centrality



Author with top
publications + top
number of
collaborators

- High density vs low density
- Multi-communities vs local community

Communities in Institutions



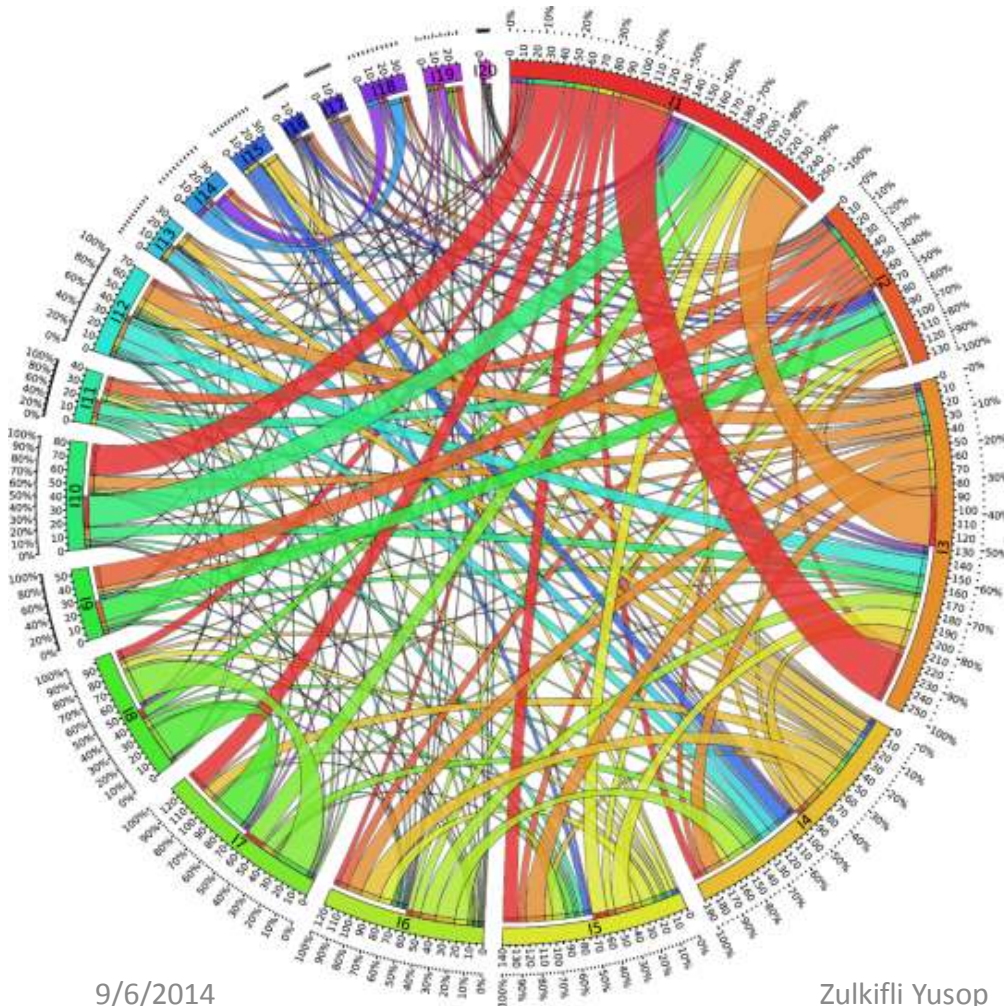
- Interaction among different communities decreased (for top 5 institutions)

Top 20 Authors Collaborations



- 5/20 do not interact with any from top 20
- Majority only collaborate with personnel from same institution (lack inter institutional collaboration for top 20)

Top 20 Institutions Collaborations



- UKM = UTM = most diverse collaborations (18/20)
- Least diverse RU = UM (13/20)
- Least diverse = FRIM (4/20)
- UPM – UKM 39X
- IIUM – UMT 27X

Foreign vs Local

Institutions	FOR	MAL
Universiti Putra Malaysia	111	41
Universiti Sains Malaysia	88	25
Universiti Kebangsaan Malaysia	57	40
Universiti Teknologi Malaysia	70	35
Universiti Malaya	73	33
Universiti Teknologi MARA	22	20
International Islamic University Malaysia	12	21
Universiti Malaysia Terengganu	21	14
Universiti Teknologi Petronas	25	10
Universiti Malaysia Sabah	25	16
Universiti Malaysia Sarawak	7	13
Malaysian Nuclear Agency	4	12
Universiti Malaysia Pahang	14	9
Forest Research Institute of Malaysia	23	4
Universiti Tun Hussein Onn Malaysia	12	4
Universiti Malaysia Perlis	7	9
Universiti Tunku Abdul Rahman	12	5
Kyoto University	24	12
Multimedia University	3	6
Universiti Tenaga Nasional	1	6

WOS/SCOPUS	Pub	Google Scholar	Pub	Total	Pub
UPM	442	UKM	155	UPM	596
USM	404	UPM	154	UKM	494
UKM	339	USM	86	USM	490
UTM	279	UM	63	UTM	342
UM	237	UTM	63	UM	300
UiTM	120	UMS	36	UiTM	144
IIUM	98	FRIM	27	IIUM	118
UMT	87	UiTM	24	UMT	108
UTP	86	UMT	21	UTP	100
UMS	62	IIUM	20	UMS	98
UNIMAS	47	UNIMAS	19	UNIMAS	66
MNA	43	NAHRIM	18	MNA	58
UMP	34	MNA	15	FRIM	54
FRIM	27	UTP	14	UMP	36
UTHM	26	FFPRI	10	UTHM	34
UniMAP	24	JIRCA	10	NAHRIM	30
UTAR	22	UTHM	8	Kyoto U	28
Kyoto U	22	DID	8	FFPRI	27
UniTEN	19	U Tokyo	8	UniMAP	26
MMU	19	U California	7	DID	26

Top 20 publishing Institutions In Water

R&D topic prioritization

Identified water R&D fields (n=175)

Absorption and Remediation	Advance flood warning system	Alternative water resources
Bio-remedial treatment	Brackish Water Biodiversity and Conservation	Capacity building and awareness
Climate change impacts	Cloud Seeding Technology	Coastal Ecology
Conjunctive use of water	Corrosion	Cumulative watershed effects
Disaster Management	Drainage technologies and water logging issues	Drinking Water Quality Standards
Ecological Engineering	Ecology of water resources, including groundwater	Eco-tourism
Environmental Policy, Legislation and Standards	Environmental Protection and Health Impact	Environmental Risk Assessment and Bionomics
Estuarine Ecology	Flood control and management	Flooding and erosion control
Freshwater and saline water interface	Freshwater Biodiversity and Conservation	Freshwater Ecology
Groundwater Assessment	Groundwater contamination and pollutant transport	Groundwater Hydrology
Impacts of climate change on flow regimes	Impacts of uncertain population growth, climate change, and transboundary issues on water supply	Improving flood carrying capacity of rivers
Integrated catchment management	Integrated Water Resource Management	Isotope Hydrology
Management of water resources and Mangrove Ecology water provision		Marine Ecology
National Biodiversity Policy	Natural Resource Management	New emerging pollutants

Identified water R&D fields (n=175)

Organic contamination in water	Palaeoecology	Partnership in water resources management
Policies and Regulations about water	Polluter pays principle	Population Ecology
Restoration of urban river channels	River and coastal flood management	River Basin Management
Rural Hydrology	Sea Water/Salt Water Intrusion	Seasonal Climate Forecasting
Service efficiency and effectiveness	Social engineering	Socio-economic impacts of sea level rise and increased river flooding
Storm Water Management	Sullage	Surface Water Hydrology
Sustainable Sanitation	Sustainable use of water	SWIFT methods for monitoring water quality
Urban and Rural Water Policy	Urban Hydrology	Urban runoff utilization
Waste assimilation	Waste Bioremediation	Waste Management
Water and Wastewater Treatment Technology	Water Availability	Water Bodies
Water Enrichment	Water Filtration	Water Footprints and Virtual water calculations
Water policy and governance	Water Pollution	Water quality criteria and standards
Water Resources Development	Water Resources Management	Water resources security
Water Security	Water Services and Utilities	Water supply and distribution
Waterborne Diseases	Watershed Ecosystems	Watershed protection
Zero-Discharge Technology	Watershed vulnerability index	Wetlands
Aquatic and Marine life	Arsenic cycling in lakes	Bio-indicators
Carbon Sequestration (Carbon Conversion)	Catchment Management	Climate change adaptation policies
Coastal hydrodynamic processes	Coastal Management	Coastal pollution

Identified water R&D fields (n=175)

Decision Support System in water resources	Decision support systems in watershed management	Degradation of aquatic ecosystem
Drought Management	Dyes and Pigments	Ecohydrology
Emerging environmental pollutants	Environmental and eco-system services	Environmental flow in rivers
Environmental Standards	Erosion Control	Estimation and Modelling of Precipitation
Footprint of water	Formulation, establishment & implementation of water <u>policy</u> , <u>legislation</u> & <u>institutions</u>	Fresh Water and Estuarine Environment
Geographical Information System (GIS) in watershed management	Global Warming/Climate Change	Greywater systems
Hazardous Waste Management	Hydraulic System	Hydrology, Hydrogeology and hydrometeorology
Industrial Effluent Treatments	Industrial Water Management	Institutional and water governance
Karst Ecology	Landscape Ecology	Limnology
Marine Water Quality Standards and Criteria	Molecular Ecology	Monitoring, remediation and conservation of water resources
Non-revenue water (NRW)	Nutrient Removal Process	Optimization of water
Physiological Ecology	Plant and Water Relation	Point and non-point source pollution
Rain Water Harvesting	Reclamation, Reuse and Recycling	Remote Sensing
River ecosystem functions	River management and rehabilitation	Role of woman in enhancing water use efficiency
Seawater and Sediment Chemistry	Seawater Chemistry	Sediment Transport and Silting
Soil Bioremediation	Solid Waste Management	Storm Water Harvesting

Identified water R&D fields (n=175)

Sustainability of watersheds	Sustainable agriculture	Sustainable decision-making for urban water systems
Toxic and Hazardous Waste	True economic value of water	Trust building with stakeholders
Urban water regulation and planning	Urban watershed remediation	Virtual water concept promotion
Waste Water Management	Water and Health	Water and wastewater treatment
Water Body Management	Water Delivery System	Water demand management
Water governance	Water Meters	Water policy
Water Quality Simulation Modelling	Water related Rules, Policies, Laws	Water resource assessment
Water resources sustainability	Water rights/permits/trading	Water Sanitary
Water tariff and subsidies	Water Treatment	Water, as a Green solvent/ Reaction Medium
Watershed sustainability index		

Water R&D fields in SC-1 and expert opinion (n=95)

Advanced and innovative technology for industrial wastewater treatment	Advanced dam technology	Advanced water treatment process
Alternative unconventional urban sanitation systems	Alternative water resources (ground water, rain water harvesting, etc.)	Assessment of freshwater withdrawal
Assessment of water use and availability	Balancing water supply versus demand	Carbon footprint of water and wastewater treatment system
Catchment/river basin management	Climate change and aquatic invasive species	Climate change and hydrologic cycle
Climate change and rainfall modeling	Coastal ecology	Coastal erosions
Coastal habitat management	Conservation and preservation of water resources	Consumer and corporate water footprint assessment
Dam modeling construction	Decentralized sanitation system	Development of best drainage design and practices that enable crops to use shallow groundwater efficiently
Drainage for ecosystem and conservation	Drainage, water logging and salinity control	Drinking water quality standards
Drinking water quality versus public health	Ecohydrology	Electromechanical equipment
Energy and water efficient cities/township	Environmental and indigenous people related issues	Environmental and social impacts

Water R&D fields in SC-1 and expert opinion (n=95)

Environmental effects of nutrients carried in drainage discharge	Environmental flow versus climate change issue	Environmental impacts assessment of effluent discharge to environment
Environmental water requirements	Erosion and sedimentation	Eutrophication
Flood management and mitigation	Fresh water ecology	Ground water quality
Groundwater hydrology	Hydrometeorology	Impacts of climate change, increased population and changing human demographics on watersheds
Impacts of climate variability on wetlands ecosystem	Impacts of irrigation on environmental and health	Improved and innovative irrigation technology (for water use reduction)
Integrated coastal zone management	Integrated urban water management	Integrated water resource management
Low carbon and energy efficient treatment system	Marine biodiversity, conservation and management	Marine ecology
Marine pollution	Micro drainage system for small scale farming	Modeling climate-related water resource stressors
Newly emerging water pollutants	Nutrients removal and management	Phytoremediation/Bioremediation technology
Policy and legislative instruments	Policy and legislative issues	Protected conservation areas in marine environment
Public awareness and participation in water resources conservation	Public participation in watershed management	Quality waters and wastewater reuse for irrigation
Rainwater harvesting for irrigation purpose	Risk assessment	River morphology

Water R&D fields in SC-1 and expert opinion (n=95)

River rehabilitation	Rural hydrology	Salt/sea water intrusion
Seawater and sediment chemistry	Social and environmental costs of watershed degradation	Storm water management
Surface water hydrology	Sustainable and integrated watershed management	Sustainable water supply management in rural areas
Technologies for controlling and monitoring non-point source pollution	Technologies for monitoring, controlling and removing diffuse and point source pollution	Terrestrial atmospheric pollution and water quality
The adaptation of urban water supply to climate change	Urban hydrology	Water and sanitation hygiene in rural areas
Water demand projection and forecasting	Water footprint	Water quality Information management and modeling
Water quality modeling	Water resource assessment and accounting	Water security challenges and mitigation measures
Water supply and demand for industry	Water supply and demand for livestock and agriculture	Waterborne pathogens and microbial risks
Water-energy-food security nexus	Water-use efficiency	Wetland modeling
Wetlands and lakes restoration	Zero discharge technology	

Field of Research (FOR)

- **MASTIC and other data base - 175**
- **Survey + SC1 + Expert opinion - 95**
- **Group into 5 categories**
 - i. **Water resources and watershed management – 39**
 - ii. **Water supply and demand – 17**
 - iii. **Irrigation and drainage – 9**
 - iv. **Sanitation, wastewater and environmental issues – 17**
 - v. **Water and climate change**

Water R&D Institution

University Research Centres (22)

No.	Univ	Research Centre	Research Focus Area
1.	UM	Water Research Centre	Wastewater treatment technology, water resource management
2.	USM	River Engineering and Urban Drainage Research Centre (REDAC)	River management, Urban Drainage Management
3	USM	Centre for Marine and Coastal Studies (CEMACS)	Marine and coastal ecosystems, Biodiversity and conservation of marine ecosystems
4	UKM	Institute for Environment and Development (LESTARI)	Environmental policy and governance including water and river basin management
5	UKM	Institute for Climate Change Studies (IKP)	Tropical Climate Change
6.	UPM	Tropical Forest Ecosystem Science Research Centre	Water Quality, Social science,
7	UPM	Smart Farming Technology Research Centre	Irrigation and Drainage Engineering
8.	UTM	Coastal and Offshore Engineering Institute (COEI)	Coastal and offshore engineering, hydraulic and coastal designs
9	UTM 9/6/2014	Institutes of Environmental & Water Resource Management (IWASA)	Waste water engineering, Water Resources Management including climate change

10	UTM	Water Research Alliance	Environmental chemistry, Eco-hydrology, Water & wastewater treatment, Green technology, Climate change, Integrated water resource management
11.	UMS	<u>Centre for Water Research (CWR)</u>	Natural aquatic environments , wastewaters, agricultural and urban development activities. Integrated Water Resource Management
12.	UMS	Borneo Marine Research Institute	Aquaculture and marine science, marine biodiversity, coastal oceanography, marine aquaculture, marine biotechnology, stock enhancement and fisheries
13.	UMT	Institute of Oceanography and Environment	Physical & geological oceanography, Biological oceanography & biodiversity, Geochemistry & marine pollution, Satellite oceanography & marine informatics
14	UMT	Institut Akuakultur Tropika (AKUATROP)	Aquaculture technology
15	UMT	Institut Bioteknologi Marin	Marine biotechnology,
16.	Unisza	East Coast Enviromental Research Institute (ESERI)	Environmental forensic
17.	UNITEN	Centre for Sustainable Technology and Environment	Sustainable Urban Drainage Systems, eco-hydrology concepts

18	UNITEN	Centre for Storm Water and Geohazard Management	Stormwater, geohazard, water quality, hydropower
19	UTP	Research Clusters (Water & Environmental Engineering)	-
20	UTP	Research Cluster (Environmental Engineering)	-
21	UTAR	Centre for Biodiversity Research (CBR)	Aquatic biology
22	UTAR	Centre for Environment and Green Technology (CEGT)	Environmental biotechnology , Water & wastewater treatment

Research Ins Gov and Private

No.	Research Centre	Research Focus Area
1.	NAHRIM	Water Resources, Coastal, Geohydrology, Water Quality, Water and Environment Management
2.	FRIM	Forest Hydrology, Climate Change, Water Quality
3.	HTC	Water Resources Management & Development, Hydrology
4.	IWK	Sewerage Management, Sewage Treatment
5.	SYABAS	Water supply, Water treatment
6.	SAJ	Water supply, Water treatment
8.	Fisheries Research Institute	Sustainable Aquaculture Technology
9.	Malaysia Nuclear Agency	Isotope application water and Natural Resources Management,

Conclusion

- Overall our R&D investment is still low
- Water issues is increasingly complex
- Research University Agenda play crucial role
- Still lack of focus – formation of water R&D Consortium

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