2014 International SWAT Conference

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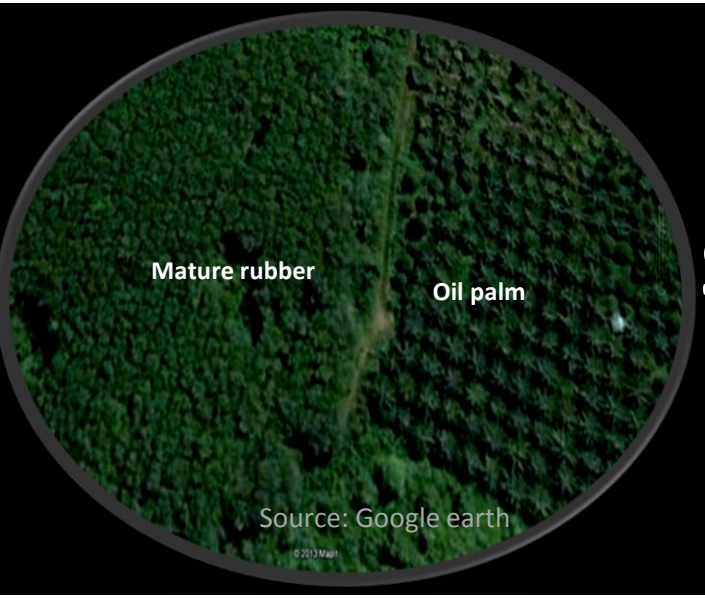

Hydrological Impact of Large Scale Conversion of Rubber to Oil Palm Plantation

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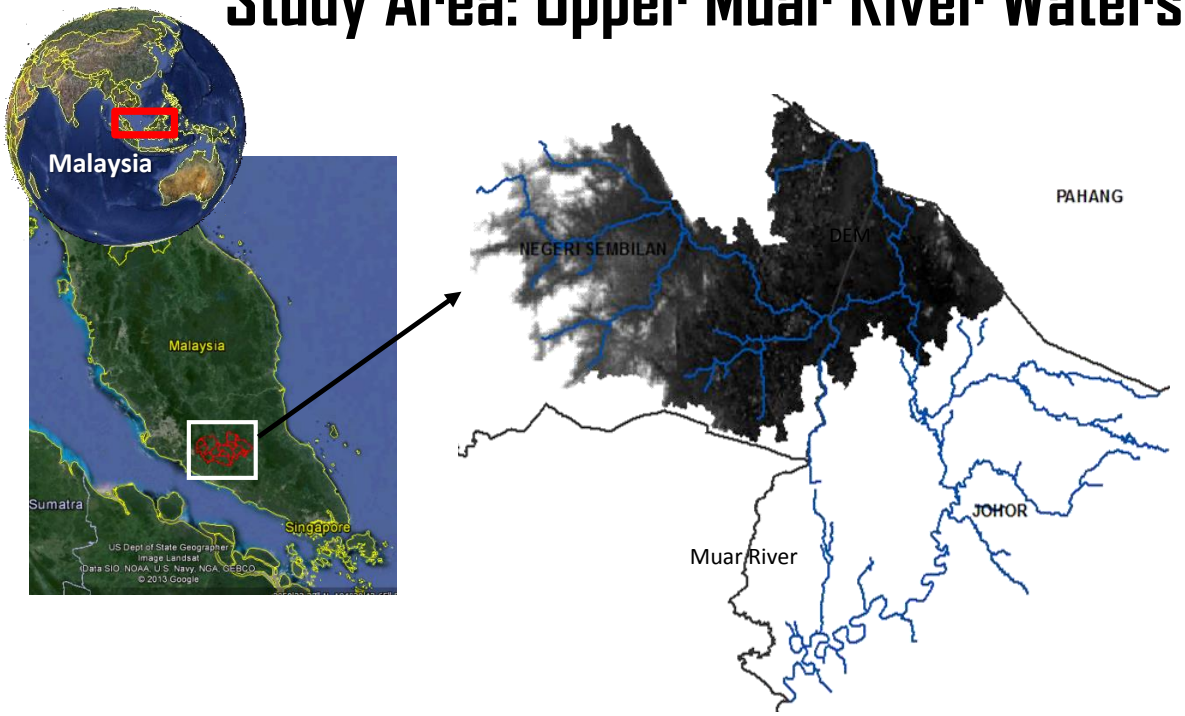
Study Area: Upper Muar River Watershed



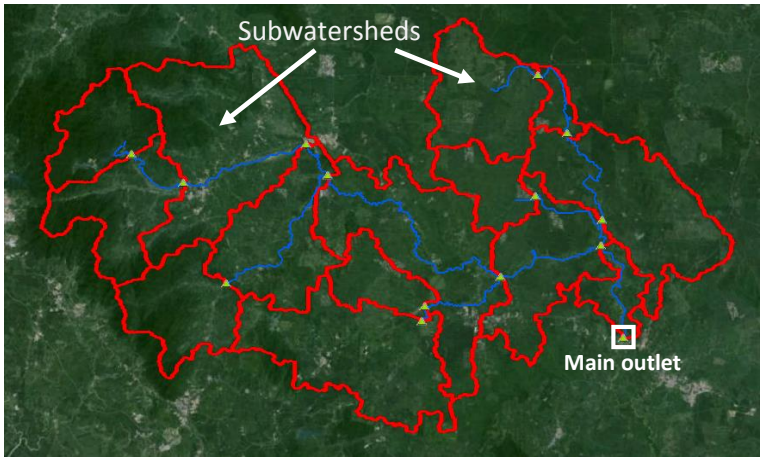


Figure : Upper part of Muar River watershed

288 km
Total stream length

2983km²
Total Wshed Area

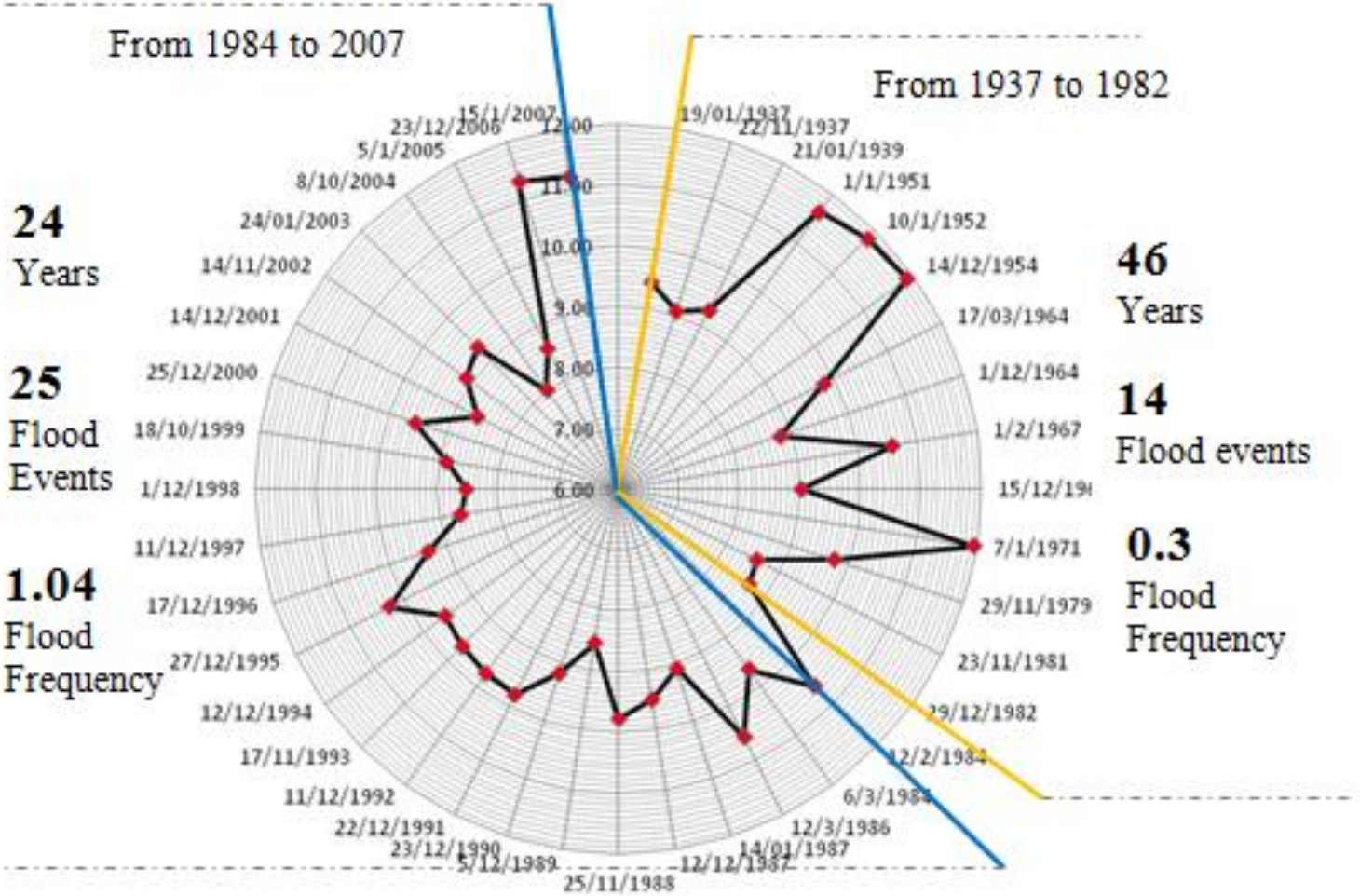
~1900 mm
Annual rainfall

Flow gauge
At Buluh Kasap (main outlet)

The Issue:

More frequent flooding downstream along the main channel, Muar River. What is the cause and what is the role of oil palm plantation.

More frequent flooding events along the main river downstream of the watershed. **Why?**



THE SUSPECT

Succession of vast tract of LULC

From original forest (up to 1960s)

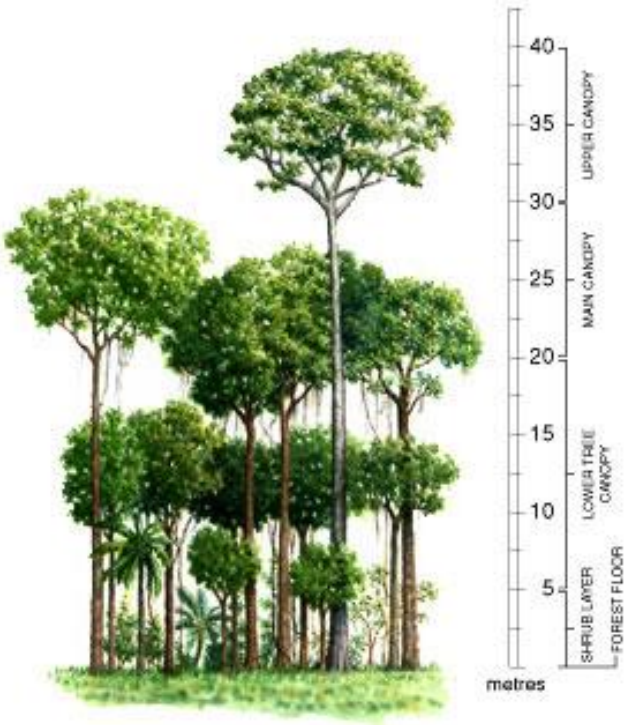
to rubber (up to late 70s)

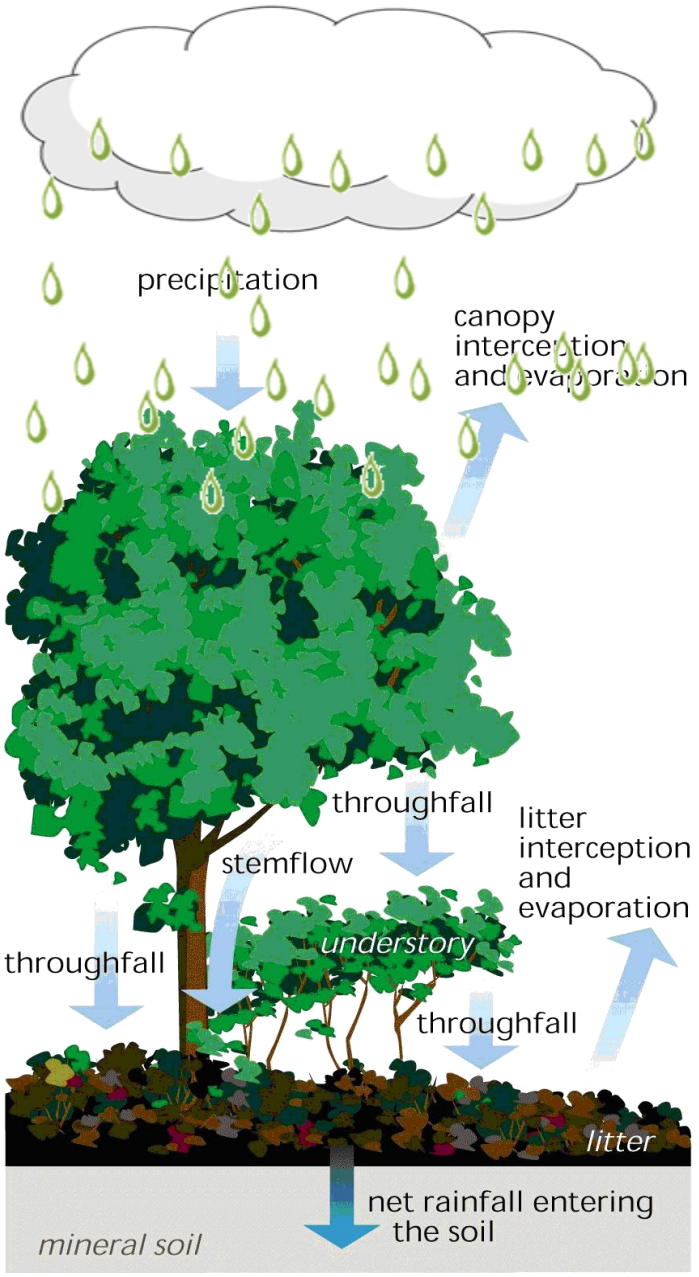
to oil palm (starting 1980s)

..different land covers hosting different types of plants with different physiologies.

Theoretically

HOW RAIN FALLS ON FORESTS……





- Only 10% of the rainfall reaches a stream as runoff.

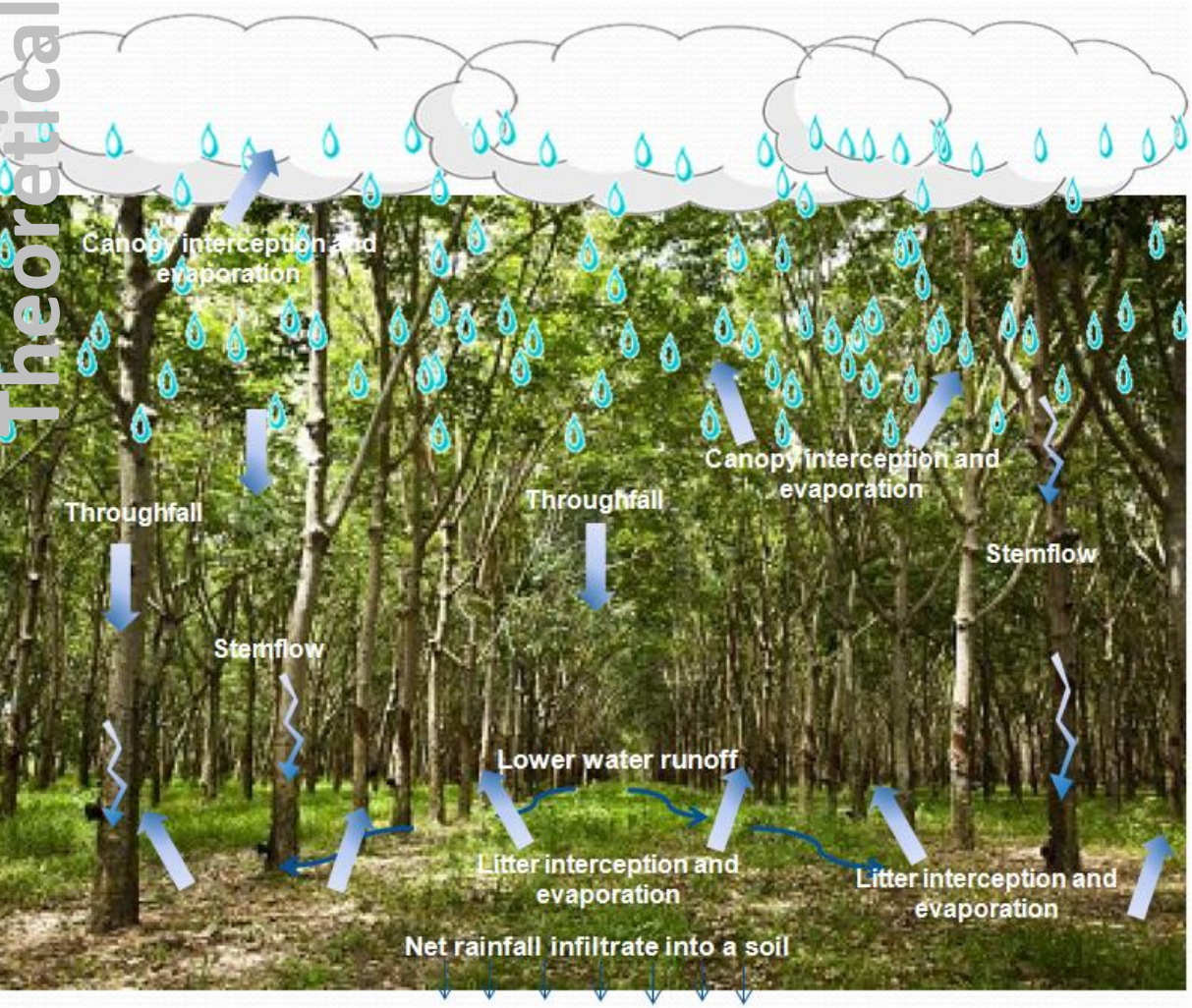
- Tree leaves, twigs, branches, trunks, and stems, along with the forest floor litter, create an extensive surface area that intercept rainwater and allow much of it to evaporate before reaching the soil

- Interception by forests and individual tree canopy is much greater than that by shrubs and other herbaceous plants (Pitman, 1989)

LAI : LAI forest is highest

HOW RAIN FALLS ON RUBBER TREES (*Hevea brasiliensis*) ....

Theoretically



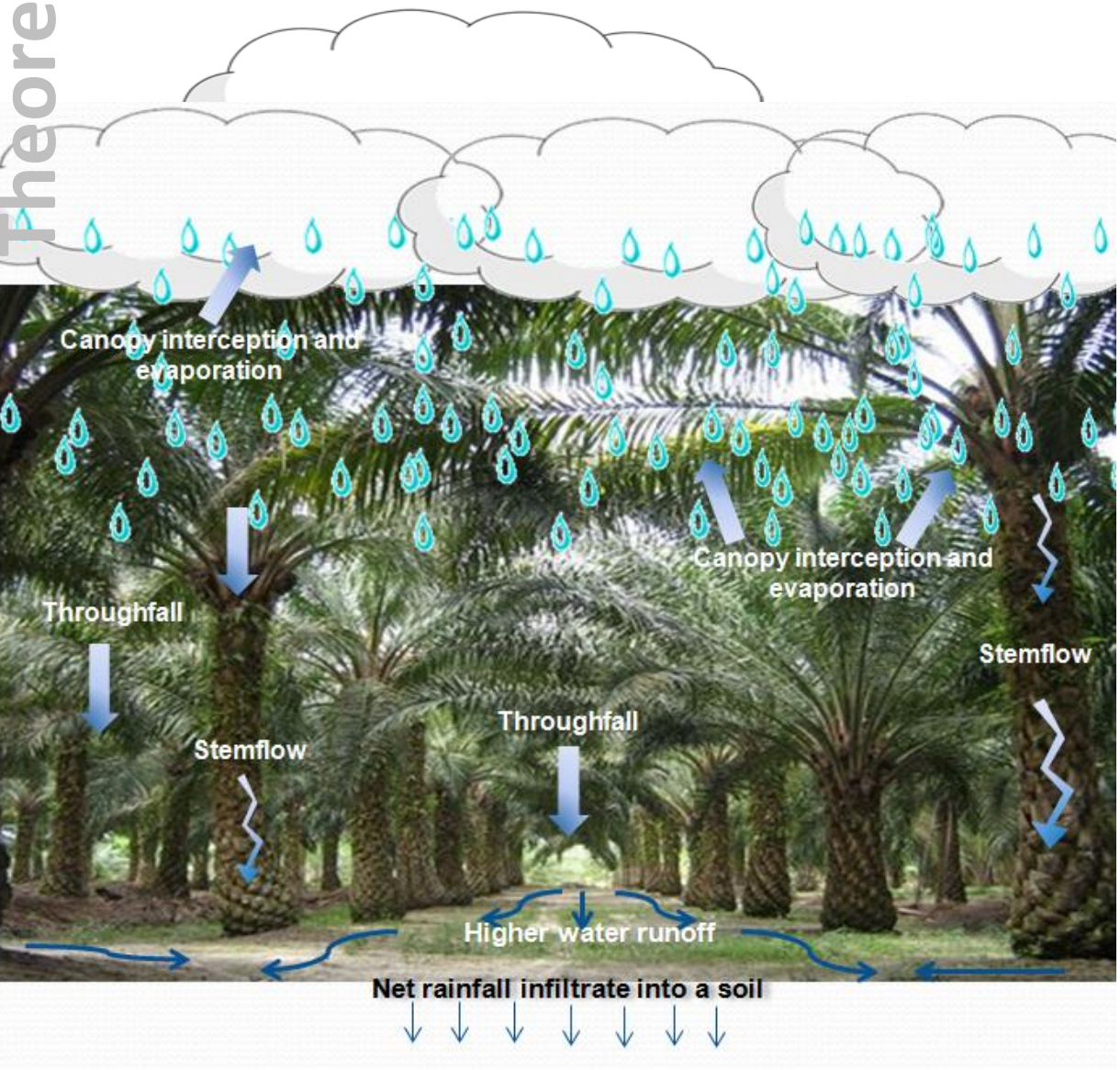
- Grow to > 40m in the wild, not exceeding 25 m under cultivation.

- During wintering (lasting for 4-6 weeks), the leaves die and fall off - creating 'sponge' effect.

- LAI : LAI rubber < LAI forest

HOW RAIN FALLS ON OIL PALMS (*Elaeis guineensis*)....

Theoretically



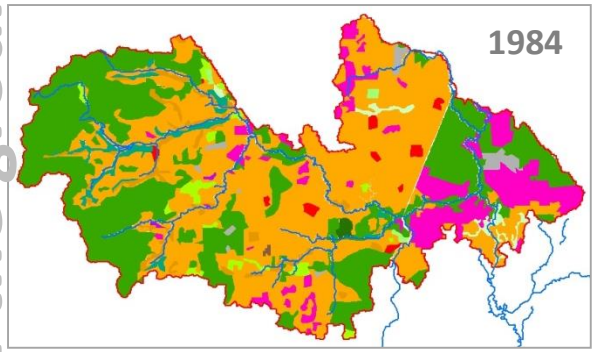
Leaf : More throughfall

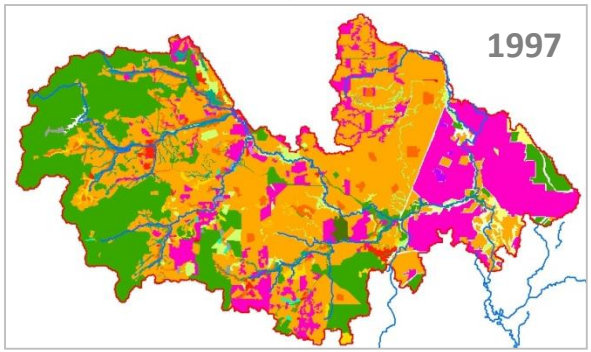
Bare Floor : Higher water runoff, higher velocity– less infiltration

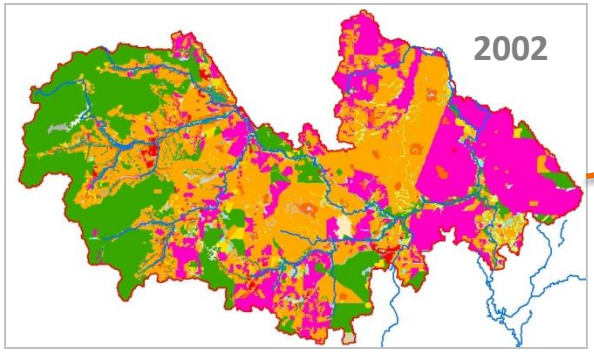
LAI: LAI oil palm palm < LAI rubber < LAI forest

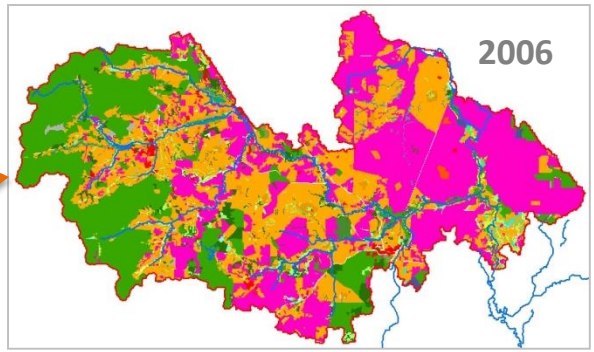
LULC Changes in Upper Muar Watershed 1984 - 2008

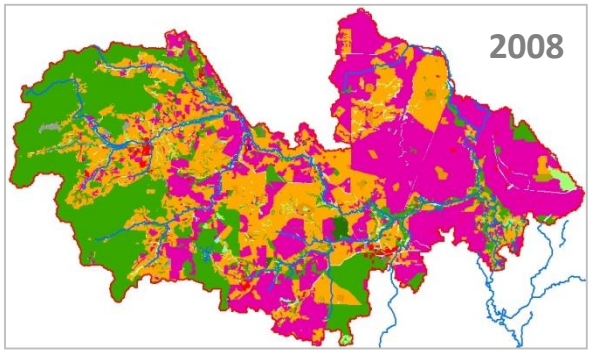
What happened on the ground

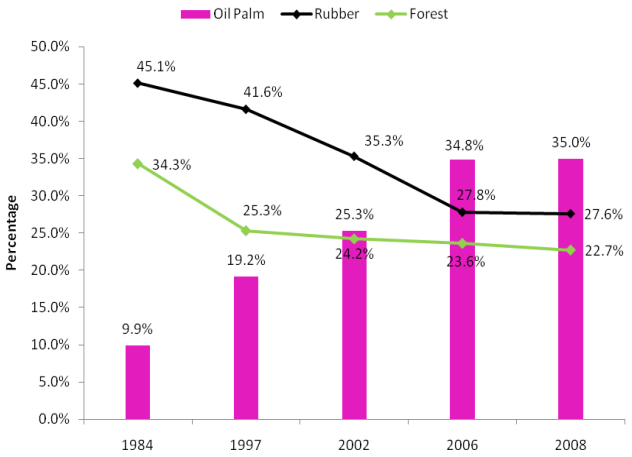












Sungai Muar

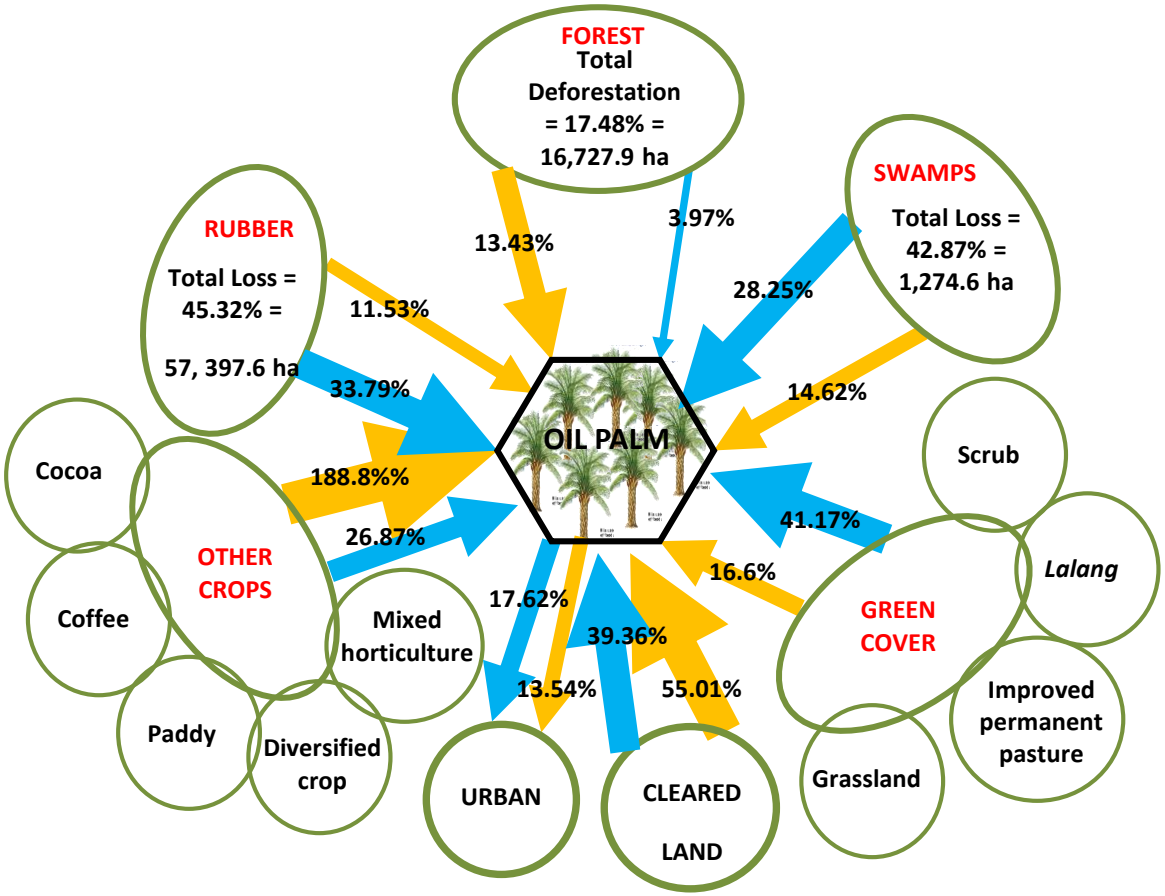
Basin

- Agricultural station
- Aquaculture
- Banana
- Cleared Land
- Cocoa
- Coconut
- Diversified crops
- Forest
- Idle Grassland/Lallang
- Marshland
- Mining _ex-mining
- Mixed Horticulture(village)
- Oil Palm
- Orchard
- Paddy
- Pasture/Ruminant
- Pond
- Poultry,Piggery _others
- Quarry _ex-quarry
- Recreational area
- Rubber
- Scrub
- Secondary forest
- Swamps
- Urban ,Residential etc
- Vegetables

Much characterized by succession of rubber by oil palms

What happened on the ground

Summary of LULC Changes in Upper Muar Watershed 1984 - 2008



Note: The percentages are based on each land use type, not total area of watershed.

45.3%

[57, 397.6 hectare]

Total Rubber Loss

17.5%

[16,727.9 hectare]

Total Deforestation

0.73%

Annual Deforestation

The Modeling

SWAT Hydrological Modeling

24 Years

5 set of land use data: 1984,1997, 2002,2006 & 2008

42 Years

Daily meteorological data: rainfall, temperature, humidity, flow & solar radiation from 1970 to 2011

42 Years

SWAT hydrological model simulated from year 1970 to 2011

WARM-UP PERIOD

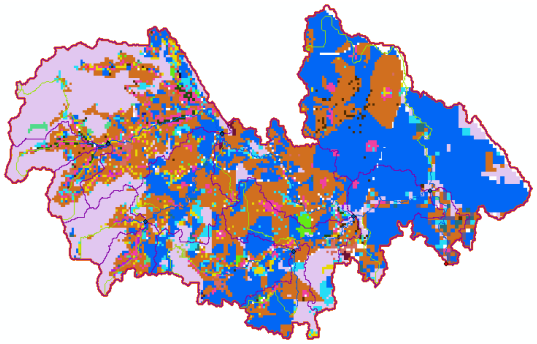
1970 to 1975

Model Calibration

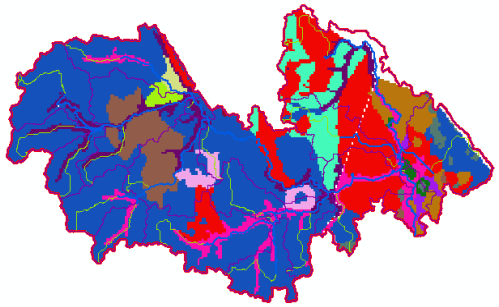
1976 to 1992

Model Validation

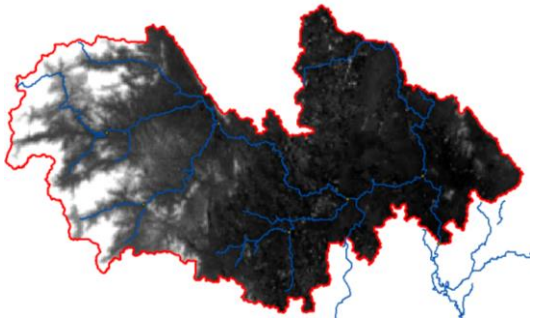
1992 to 2011



LAND USE (1984, 1997, 2002,2006,2008)



SOIL DATA

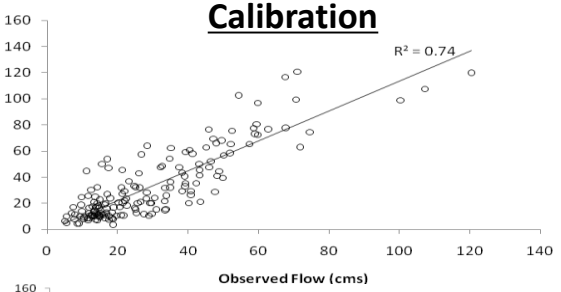


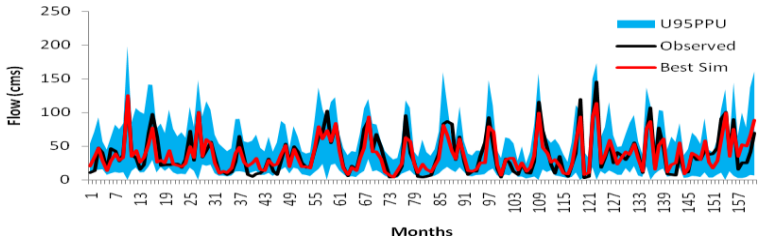
ASTER DEM (30 Meter)

The Results

Calibration

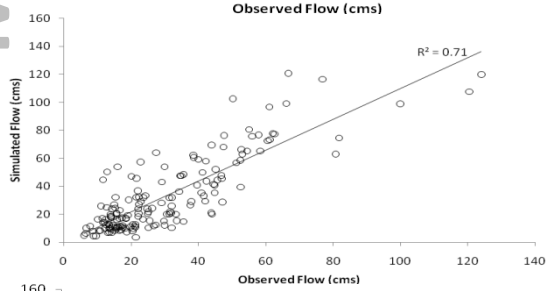
Validation

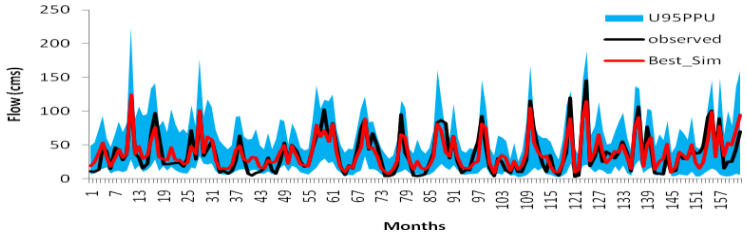




NSE 1984: 0.79

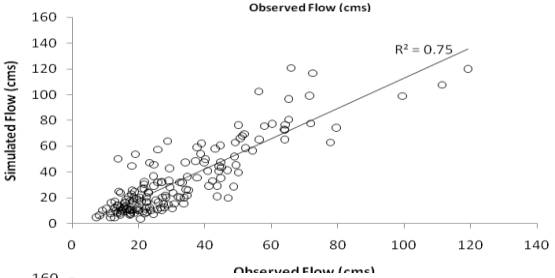
Year 1997

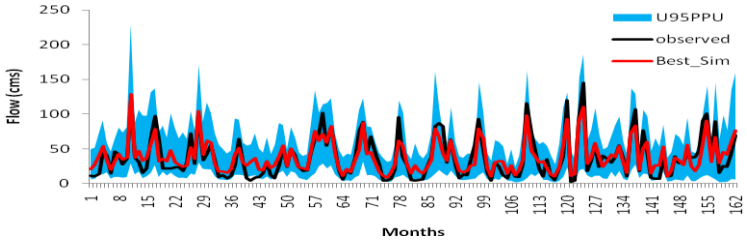




NSE 1997: 0.80

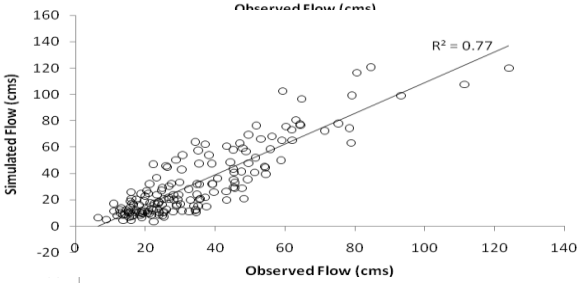
Year 2002

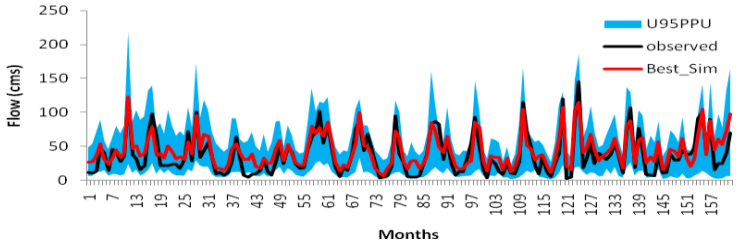




NSE 2002: 0.78

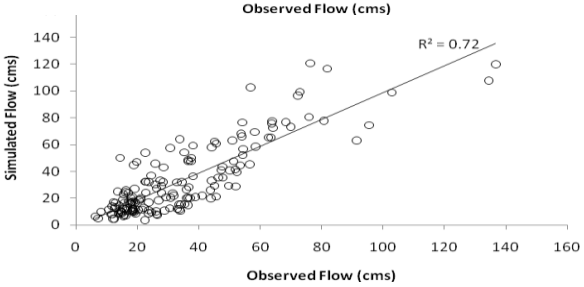
Year 2006

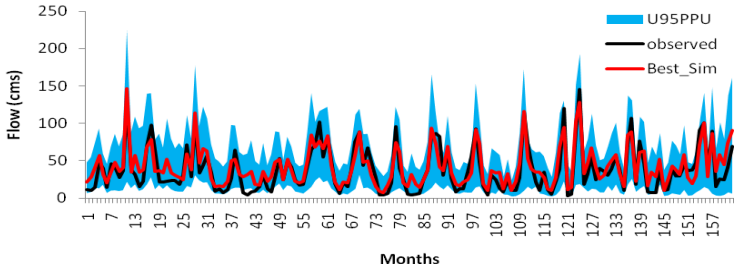




NSE 2006: 0.74

Year 2008

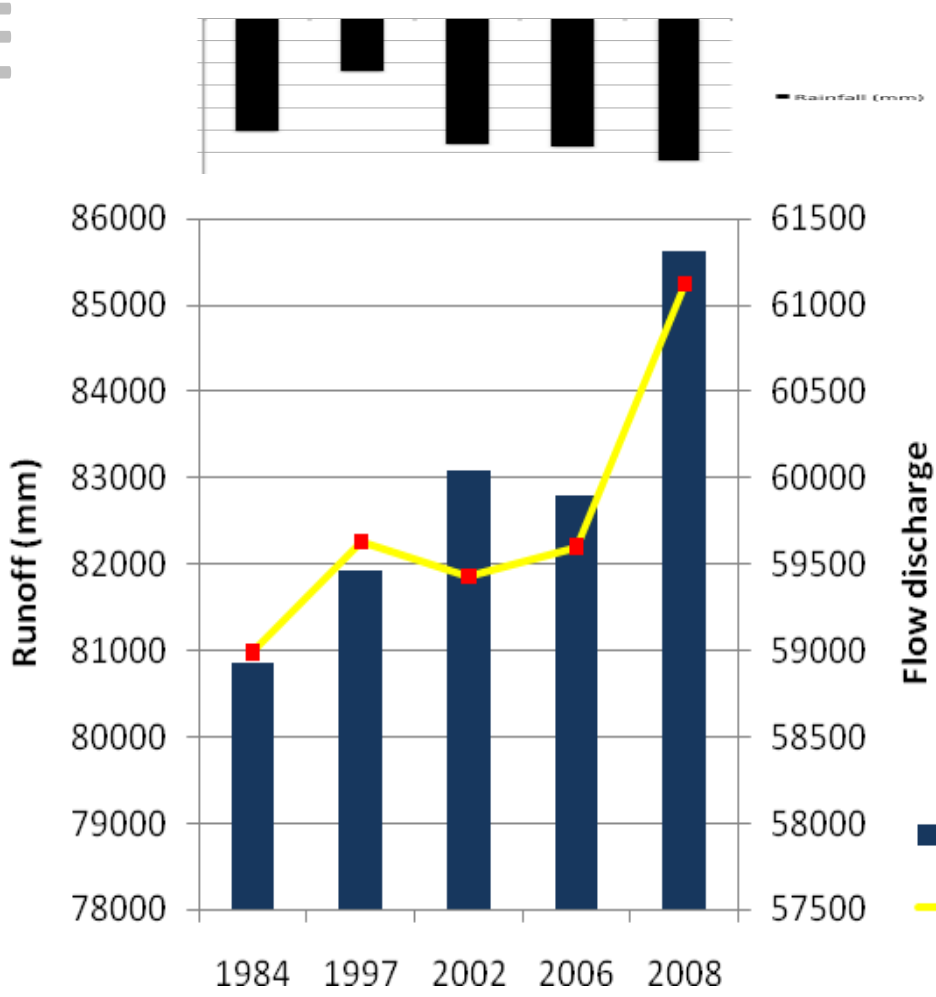




NSE 2008: 0.76

Results

Comparison of land use change with runoff and flow increase/decrease



Year	Runoff (mm)	Flow Discharge (cms)
1984 to 1997	1272.6	527.5
1997 to 2002	-399.0	585.5
2002 to 2006	348.4	-148.1
2006 t0 2008	3045.2	1416.1

OP Canopy Behaviour

- 40 fronds/year, 2 to 4 years old; then declines with age stabilizing after 8-12 years at about 20-24 fronds/year.

- Leaf production of grove palm is much lower. In Malaysia, leaf production rate is 20.7 by 10 to 15 years old oil palm (Corley *et al.,* 1971).

- Leaflets number some 250-300 per mature leaf and are up to 1.3 m long and 6 cm broad.

- As oil palms age, their leaves not as good as the younger trees and the canopy also not as dense.

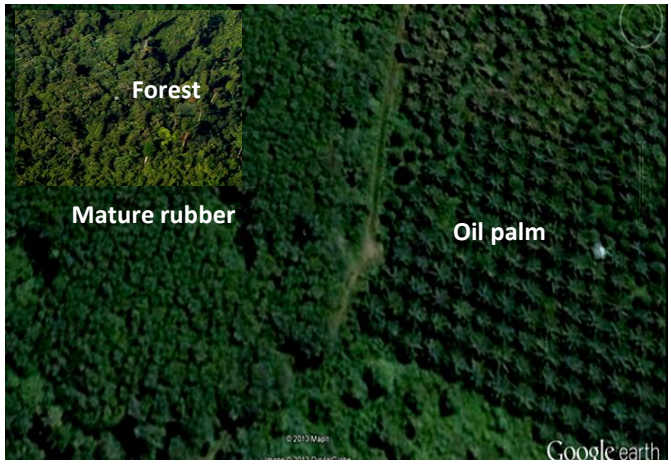
1 year old

5 years old

7-10 years old

8-12 years old

20 to 25 years old



Source: Google earth

Groundcover

- About 60 to 70 plant species (forages) growing under the young OP and rubber plantation but the number decrease to 20 to 30 species under older trees.

- The legumes species usually dominated during the first to five years of oil palm and rubber planting. During first 8-10 months of land clearing, legume planted for soil erosion control.

- In rubber and oil palm, the percentage of light under the tree canopies drops to below 20% of full sunlight at the tree age of 6 to 7 years due to canopy close up.

Oil palm specifics:

- Grasses, legumes and broadleaf species dominated the native forage in the first five years after planting.

- Once the canopy has closed up, the legume coverage decreases after the fifth year. Proportions of grasses have small changes but as oil palm trees getting mature the broadleaf species decline.

Oil palm 5 years old

Oil palm 10 to 15 years

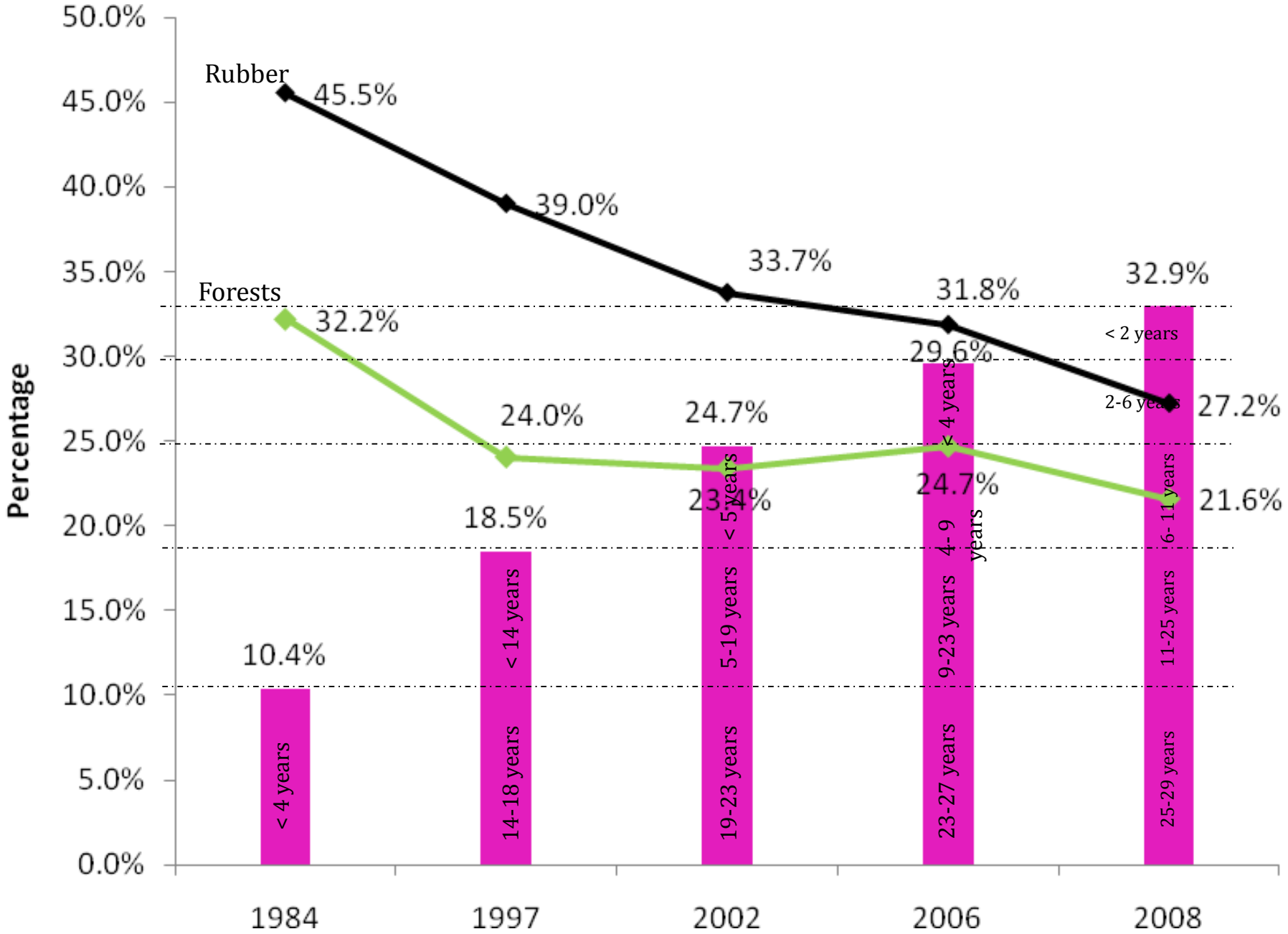
Rubber trees 4 years old

Rubber trees 10 years old

Source: Location in Muar river watershed

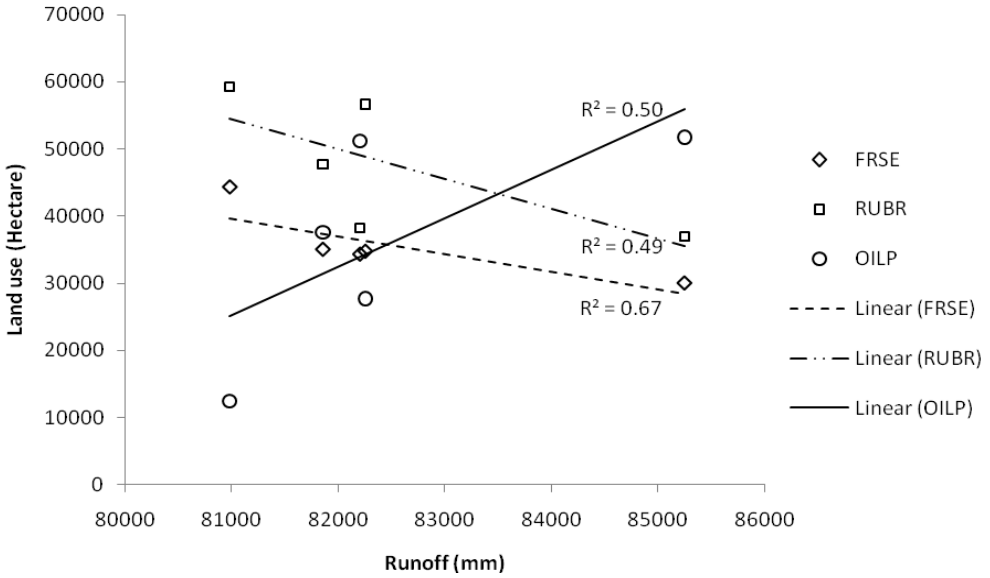
Ground cover condition in oil palm and rubber plantation

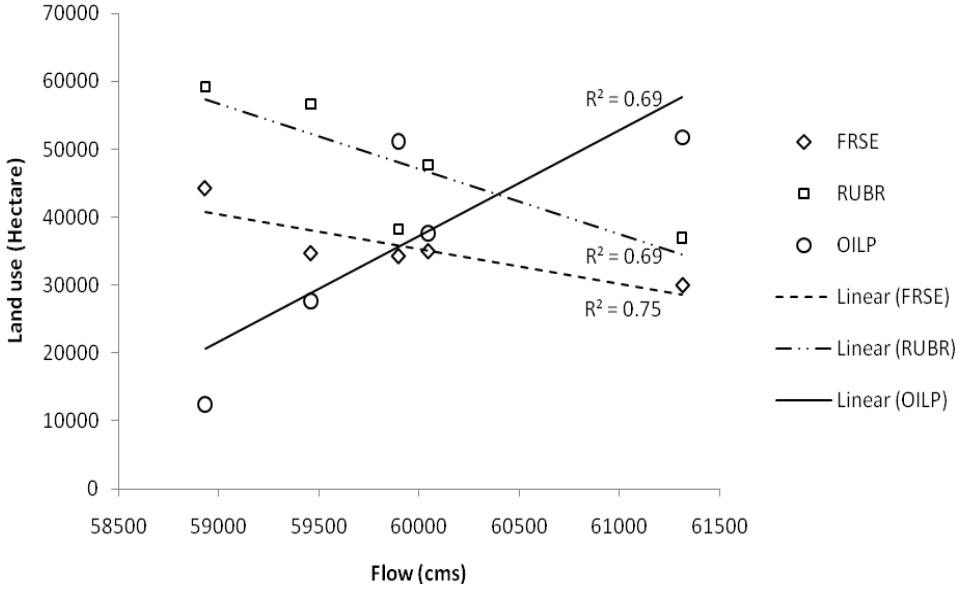
The Interpretation



Changes in dominant land covers showing ages of oil palms

Conclusion





- Positive correlation between size of oil palm area and volume of runoff and flow.

- Negative correlation between acreage of forest and rubber and volume of runoff and flow.

.....Conclusion

- **Large scale conversion of rubber to oil palm contributes to increase in frequency and magnitude of flooding.**

- **Age of oil palms too play a factor as the canopy and groundcover of OP plantation deteriorrates with age.**
  - At the early age, oil palm has denser canopy and maintained with complete groundcover reducing the amount of runoff and flow.
  - As it gets older, oil palm's structure becomes simpler with less dense canopy and ground cover.

- **Proper stormwater management akin to LID is necessary even for the rural oil palm plantation to prevent monsoonal flooding.**

- **SWAT is capable of doing hydrology in heavy-rainfall tropical monoculture (rubber, oil palm) environment.**

Thank You