

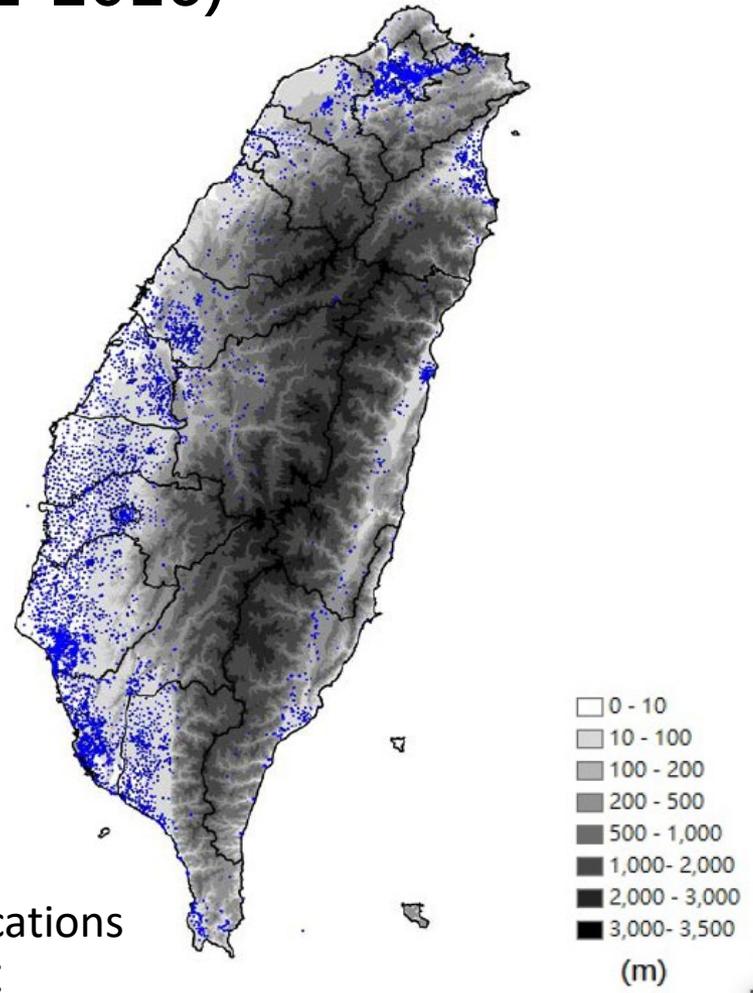
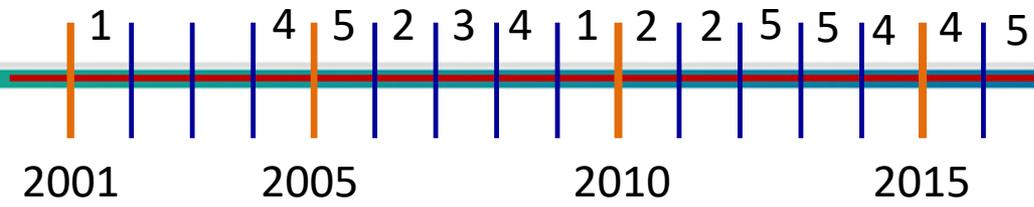
聯合風險分析方法於淹水災害之應用

林媿瑛、吳宜昭

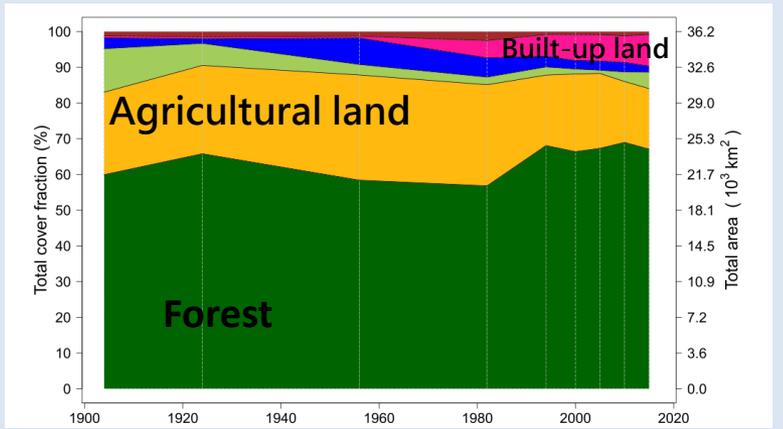
CWB天氣分析與預報研討會
2020.10.14

淹水事件

47 flood events
(2001-2016)

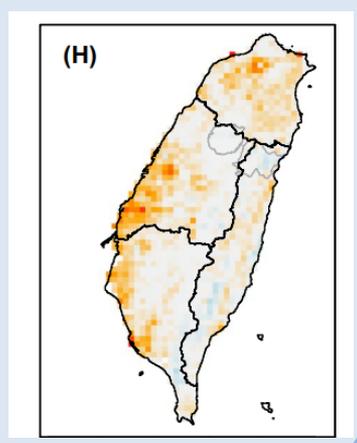
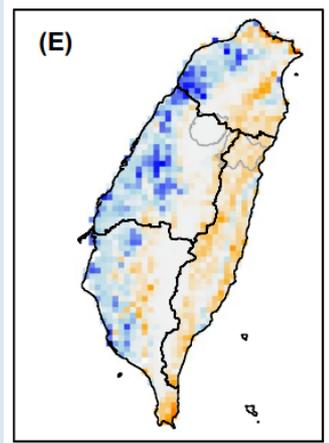


Chen et al. (2019) Scientific Reports



Agricultural land

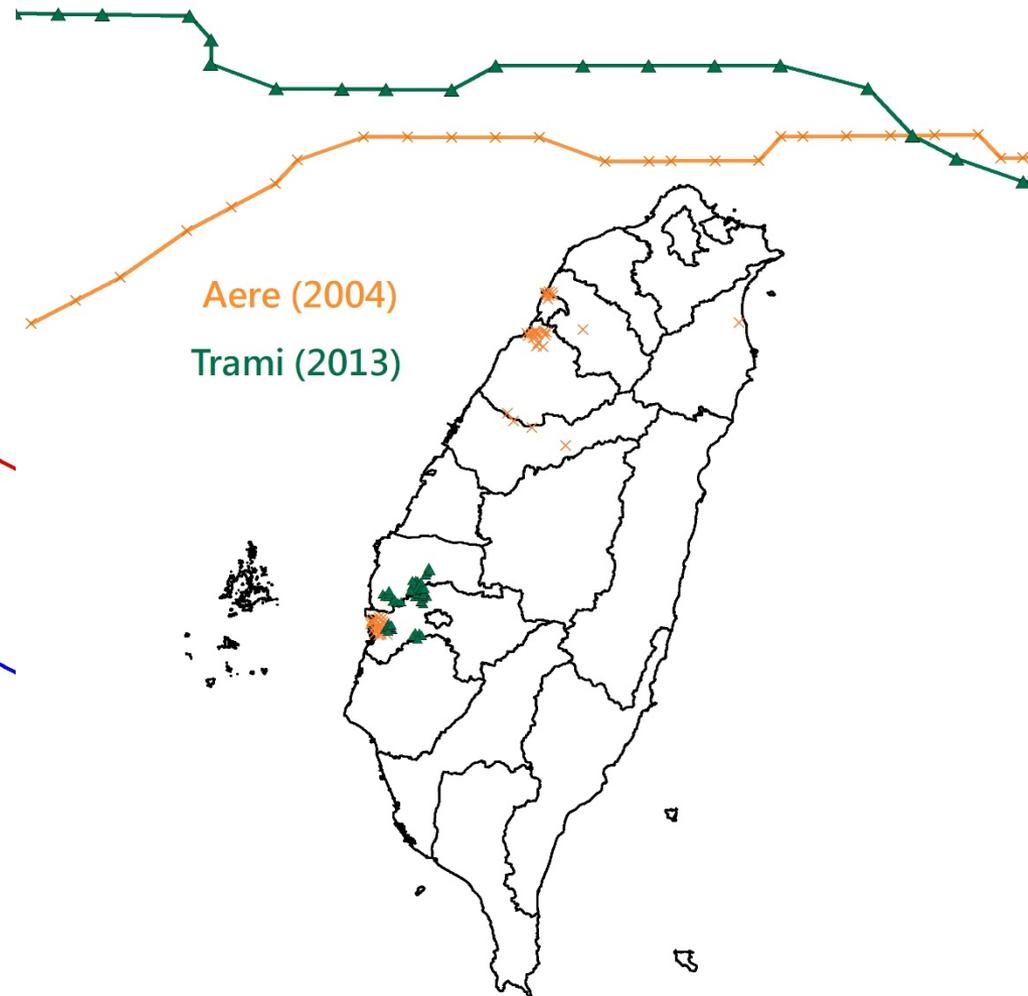
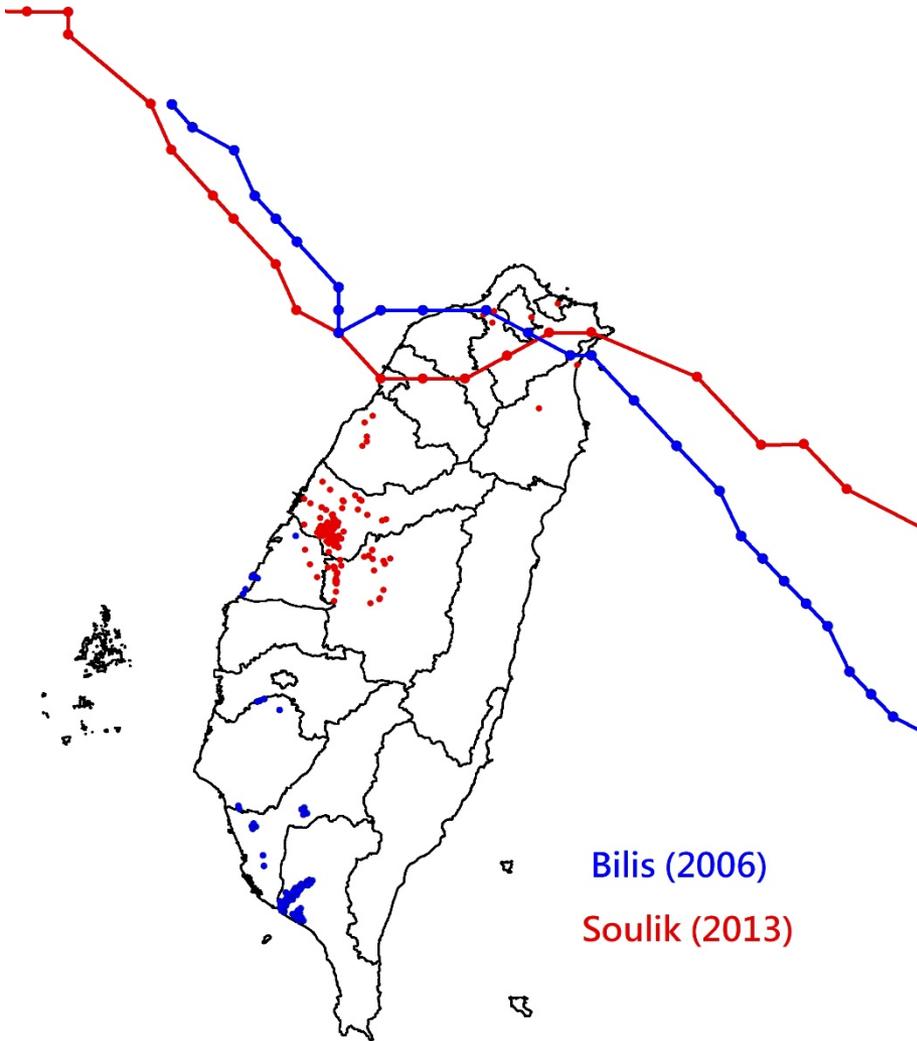
Built-up land



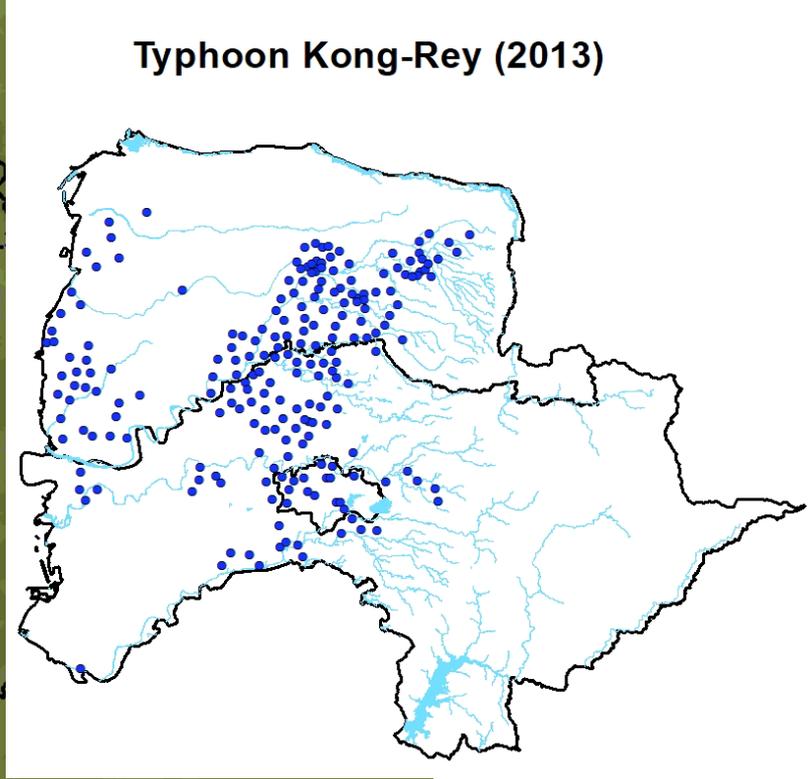
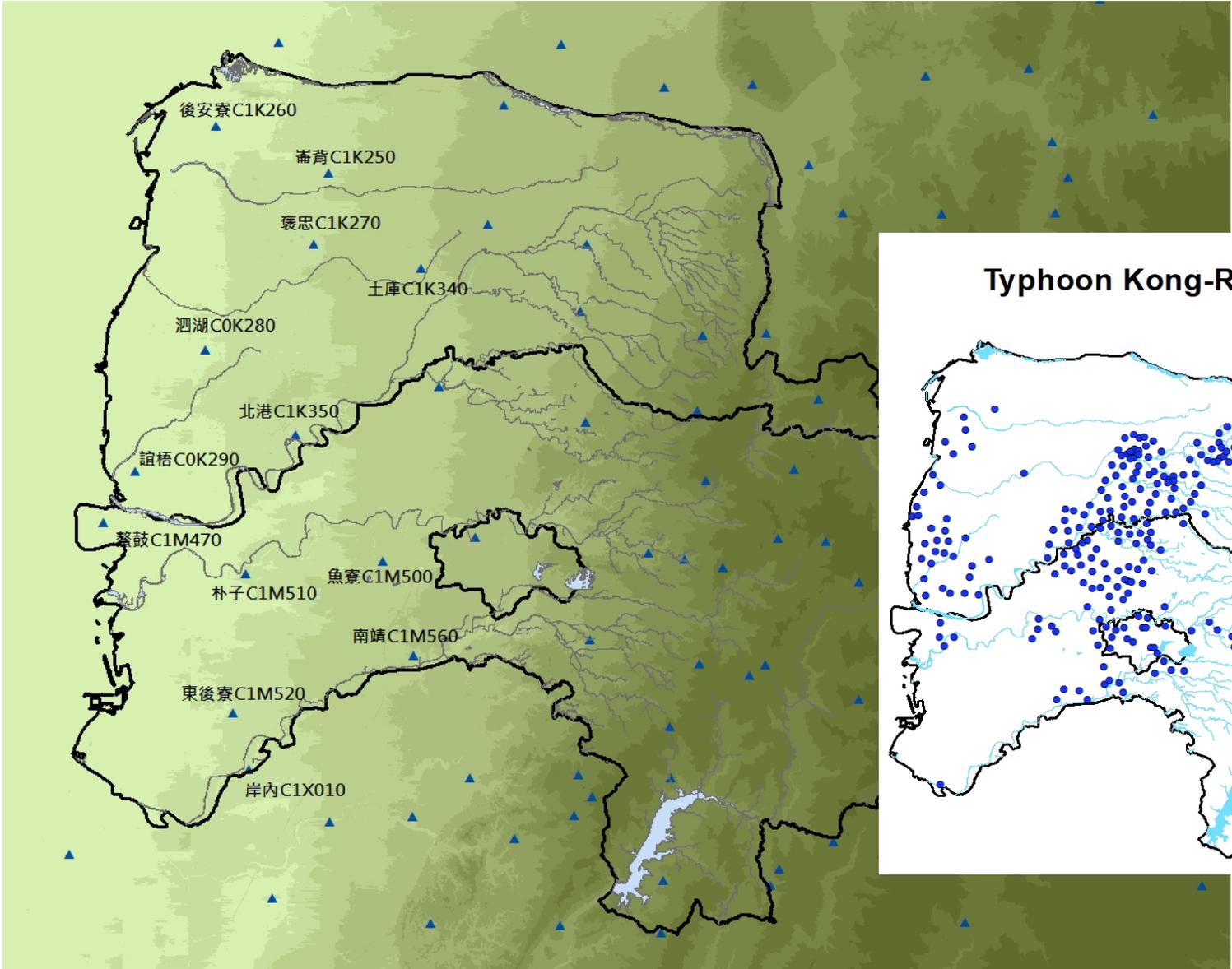
Blue color: loss

Orange color: gain

淹水位置 與 颱風路徑



淹水位置 與 地形



淹水事件 和 雨量 (單影響因子)

淹水事件數目/2001-2015強降雨事件

| 累積雨量 (mm)\雨量站 | 1h | 3h | 6h | 9h | 12h | 24h |
|---------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 鰲鼓 | $\frac{11}{31}$ | $\frac{9}{32}$ | $\frac{11}{32}$ | $\frac{12}{32}$ | $\frac{13}{31}$ | $\frac{13}{35}$ |
| 泗湖 | $\frac{13}{36}$ | $\frac{13}{37}$ | $\frac{15}{36}$ | $\frac{12}{38}$ | $\frac{14}{39}$ | $\frac{13}{39}$ |
| 誼梧 | $\frac{8}{33}$ | $\frac{10}{33}$ | $\frac{11}{35}$ | $\frac{13}{33}$ | $\frac{14}{35}$ | $\frac{13}{33}$ |
| 朴子 | $\frac{11}{29}$ | $\frac{13}{28}$ | $\frac{13}{31}$ | $\frac{15}{31}$ | $\frac{16}{34}$ | $\frac{15}{35}$ |

鰲鼓雨量站 (C1M470)

累積雨量/降雨事件代號

| | | | | | | | | | | | |
|-----|------|-----|------|-----|------|-----|------|-----|------|-----|------|
| 100 | 4549 | 166 | 4549 | 204 | 4549 | 291 | 4549 | 380 | 4549 | 529 | 4202 |
| 82 | 6065 | 152 | 6065 | 178 | 6065 | 230 | 6065 | 334 | 4202 | 464 | 4549 |
| 68 | 7442 | 97 | 5270 | 141 | 4202 | 212 | 4202 | 284 | 4201 | 412 | 6065 |
| 68 | 5270 | 97 | 1243 | 127 | 1243 | 132 | 4908 | 269 | 6065 | 408 | 4550 |
| 64 | 5759 | 96 | 4202 | 115 | 4201 | 178 | 5344 | 246 | 4908 | 338 | 4909 |
| 63 | 1961 | 95 | 5337 | 112 | 4908 | 175 | 1243 | 240 | 5344 | 322 | 4908 |
| 62 | 2796 | 90 | 4201 | 108 | 6727 | 164 | 4201 | 218 | 1985 | 317 | 4201 |
| 60 | 1243 | 88 | 4908 | 108 | 2042 | 148 | 6727 | 214 | 4627 | 296 | 4627 |
| 56 | 4899 | 86 | 1876 | 108 | 5270 | 148 | 1984 | 208 | 6417 | 288 | 4628 |
| 55 | 5337 | 82 | 5724 | 100 | 5337 | 142 | 4627 | 203 | 1984 | 282 | 6066 |
| 54 | 890 | 80 | 7546 | 96 | 5344 | 138 | 5688 | 194 | 1243 | 279 | 5337 |
| 54 | 4908 | 76 | 4584 | 90 | 4256 | 133 | 6417 | 172 | 5336 | 274 | 5344 |
| 52 | 4202 | 76 | 2042 | 90 | 5688 | 130 | 2042 | 168 | 6727 | 244 | 1985 |
| 52 | 5633 | 75 | 1984 | 90 | 211 | 125 | 4256 | 164 | 2043 | 244 | 6417 |
| 51 | 5724 | 74 | 6727 | 90 | 7111 | 124 | 211 | 162 | 6064 | 243 | 5345 |
| 50 | 2042 | 73 | 7538 | 88 | 1984 | 114 | 1985 | 162 | 1643 | 239 | 1644 |
| 50 | 5759 | 72 | 5759 | 88 | 5759 | 113 | 7538 | 159 | 6816 | 238 | 1643 |
| 50 | 4584 | 71 | 890 | 88 | 890 | 113 | 113 | 158 | 5688 | 214 | 1984 |
| 50 | 1876 | 70 | 70 | 87 | 87 | 113 | 113 | 158 | 5688 | 211 | 7547 |
| 49 | 5336 | 70 | 70 | 87 | 87 | 113 | 113 | 158 | 5688 | 209 | 891 |
| 48 | 7546 | 70 | 70 | 87 | 87 | 113 | 113 | 158 | 5688 | 208 | 1309 |
| 48 | 4202 | 70 | 70 | 87 | 87 | 113 | 113 | 158 | 5688 | 208 | 1309 |
| 48 | 4202 | 70 | 70 | 87 | 87 | 113 | 113 | 158 | 5688 | 204 | 6817 |
| 47 | 4256 | 68 | 5688 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 46 | 7538 | 68 | 5688 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 46 | 1644 | 68 | 5688 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 45 | 4550 | 68 | 5344 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 44 | 5290 | 68 | 5688 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 44 | 3790 | 67 | 7111 | 75 | 7111 | 100 | 3183 | 136 | 2042 | 193 | 6418 |
| 44 | 1984 | 66 | 5290 | 74 | 2075 | 100 | 3183 | 136 | 2042 | 196 | 4256 |
| 43 | 211 | 66 | 1965 | 74 | 2075 | 98 | 5336 | 132 | 162 | 184 | 6064 |
| 42 | 6727 | 65 | 5644 | 73 | 3183 | 96 | 4550 | 131 | 5633 | 182 | 6816 |
| 41 | 2376 | 64 | 2075 | 72 | 5759 | 94 | 1309 | 130 | 1309 | 180 | 4203 |
| 40 | 1965 | 64 | 5001 | 72 | 1961 | 90 | 3183 | 128 | 6418 | 180 | 7539 |
| 40 | 4158 | 62 | 3087 | 71 | 8179 | 90 | 6385 | 127 | 5337 | 179 | 5336 |
| 40 | 4851 | 62 | 3872 | 71 | 5290 | 90 | 2377 | 126 | 7538 | 179 | 890 |
| 40 | 1840 | 62 | 3868 | 70 | 7442 | 89 | 7824 | 126 | 6817 | 178 | 7548 |
| 40 | 75 | 62 | 5633 | 70 | 6385 | 89 | 3505 | 125 | 2415 | 172 | 2043 |
| 39 | 5344 | 60 | 4899 | 70 | 5644 | 88 | 5724 | 124 | 211 | 171 | 5751 |
| 38 | 7806 | 59 | 3133 | 68 | 5633 | 88 | 3868 | 120 | 4584 | 168 | 6727 |
| 38 | 7111 | 58 | 3790 | 68 | 3183 | 88 | 1876 | 120 | 3133 | 166 | 5688 |
| 37 | 5688 | 57 | 7106 | 68 | 2766 | 87 | 3872 | 119 | 7539 | 166 | 4584 |
| 36 | 4546 | 55 | 8179 | 67 | 2075 | 87 | 3504 | 119 | 3183 | 159 | 4955 |
| 36 | 1928 | 55 | 7806 | 66 | 5001 | 86 | 5644 | 116 | 2377 | 157 | 7546 |
| 36 | 4627 | 55 | 6417 | 66 | 1965 | 86 | 1644 | 113 | 589 | 156 | 7111 |

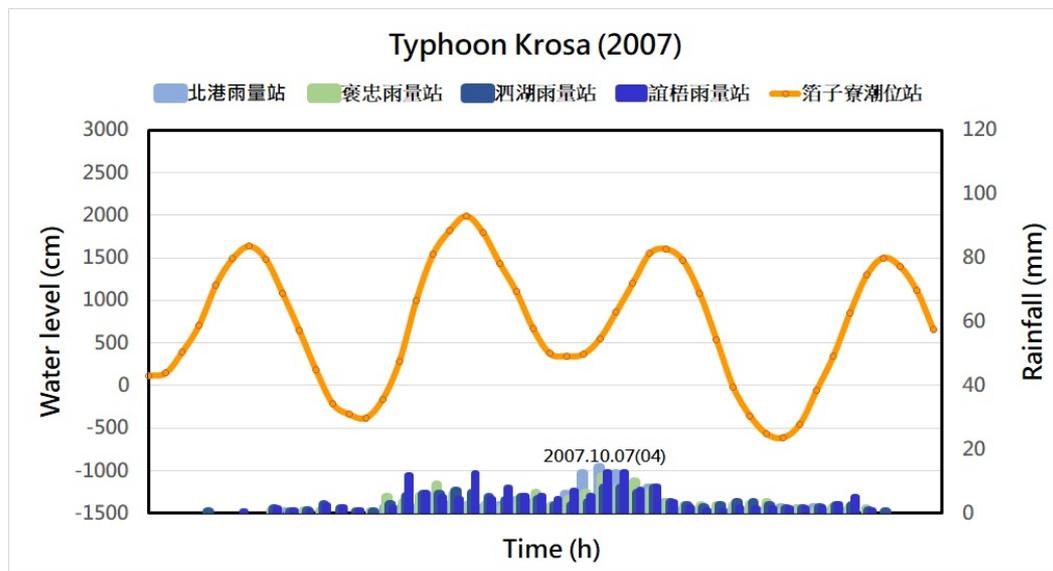
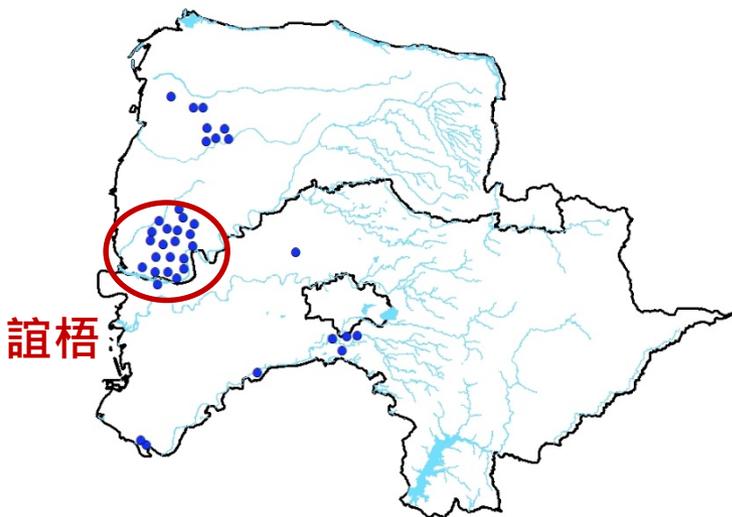


右表為1993-2015之50大強降雨事件

不同延時: 1 h 3 h 6 h 9 h 12 h 24 h

淹水事件 (未達降雨警戒但有淹水)

Typhoon Krosa (2007)



誼梧 (口湖鄉)

| 時間 | 雨量 | 警戒 | |
|----|----|-----|-----|
| | | 二級 | 一級 |
| 1H | 0 | 40 | 50 |
| 3H | 0 | 80 | 90 |
| 6H | 0 | 110 | 130 |

二級警戒：

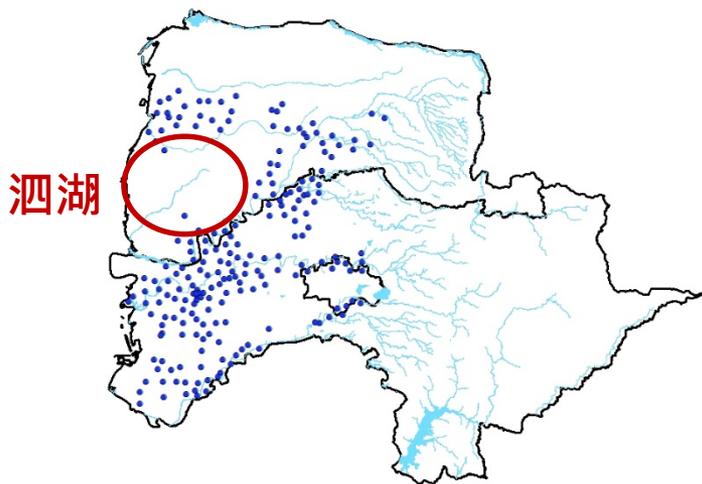
轄內易淹水村里及道路可能三小時內開始積淹水。

一級警戒：

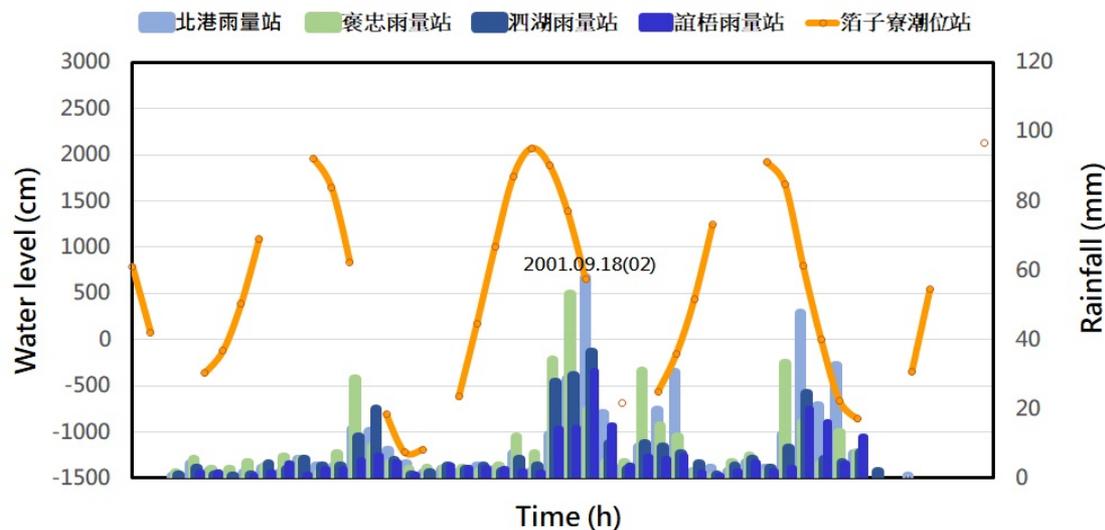
轄內易淹水村里及道路可能已經開始積淹水。

淹水事件 (達降雨警戒但未淹水)

Typhoon Nari (2001)



Typhoon Nari (2001)



四湖 (四湖鄉)

| 時間 | 雨量 | 警戒 | |
|----|----|-----|-----|
| | | 二級 | 一級 |
| 1H | 0 | 40 | 50 |
| 3H | 0 | 80 | 90 |
| 6H | 0 | 110 | 130 |

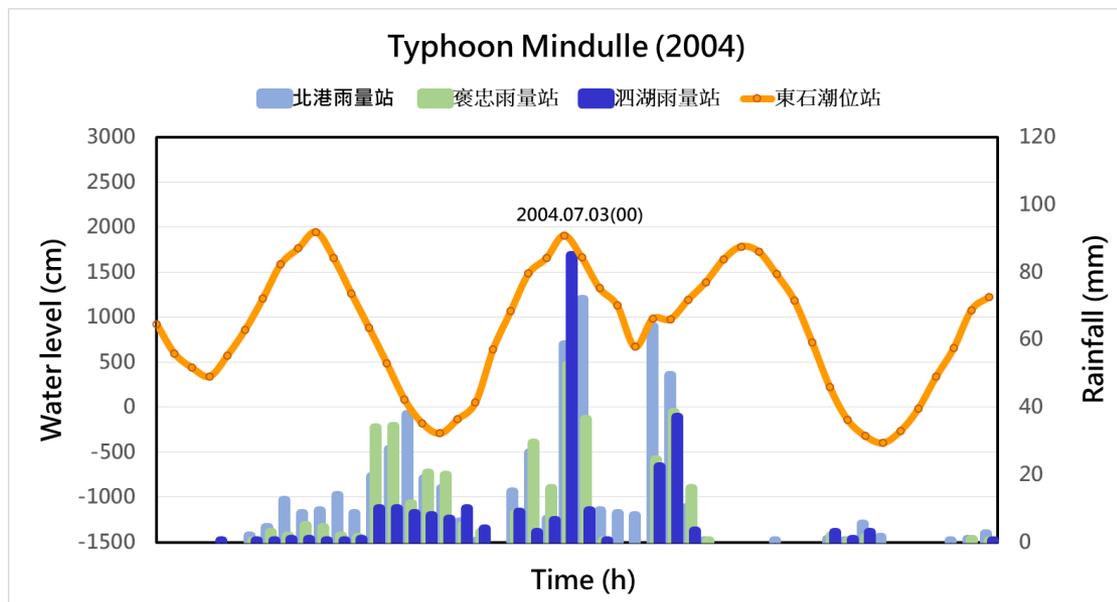
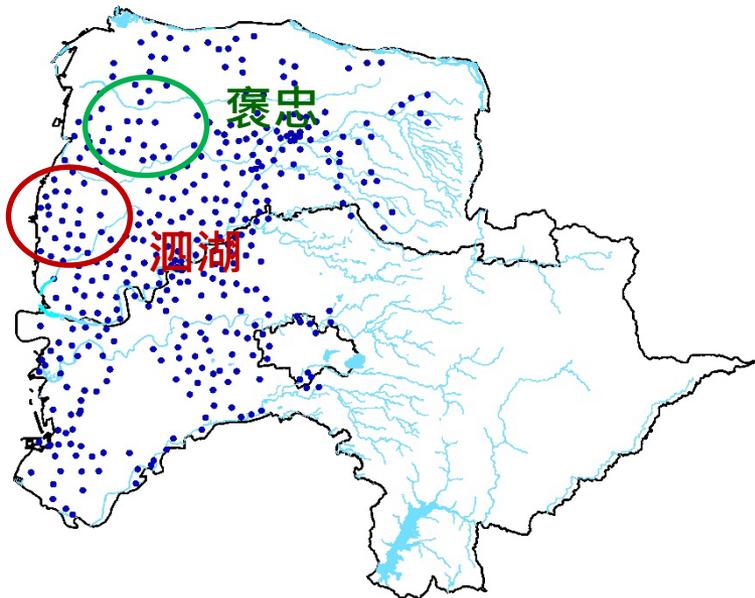
二級警戒：

轄內易淹水村里及道路可能三小時內開始積淹水。

一級警戒：

轄內易淹水村里及道路可能已經開始積淹水。

淹水事件



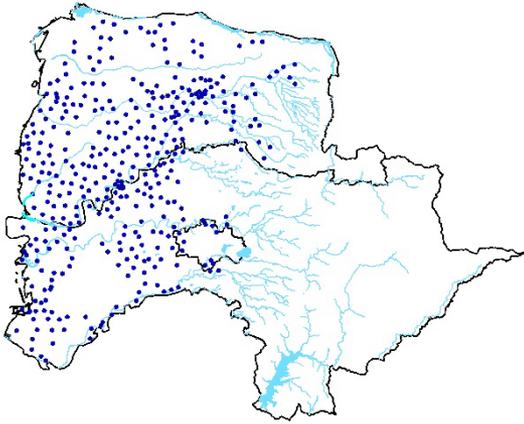
| ● 四湖 (四湖鄉) | | | | |
|------------|----|-----|-----|--|
| 時間 | 雨量 | 警戒 | | |
| | | 二級 | 一級 | |
| 1H | 0 | 40 | 50 | |
| 3H | 0 | 80 | 90 | |
| 6H | 0 | 110 | 130 | |

| ● 北港 (北港鎮) | | | | |
|------------|----|-----|-----|--|
| 時間 | 雨量 | 警戒 | | |
| | | 二級 | 一級 | |
| 1H | 0 | 50 | 60 | |
| 3H | 0 | 90 | 100 | |
| 6H | 0 | 120 | 140 | |

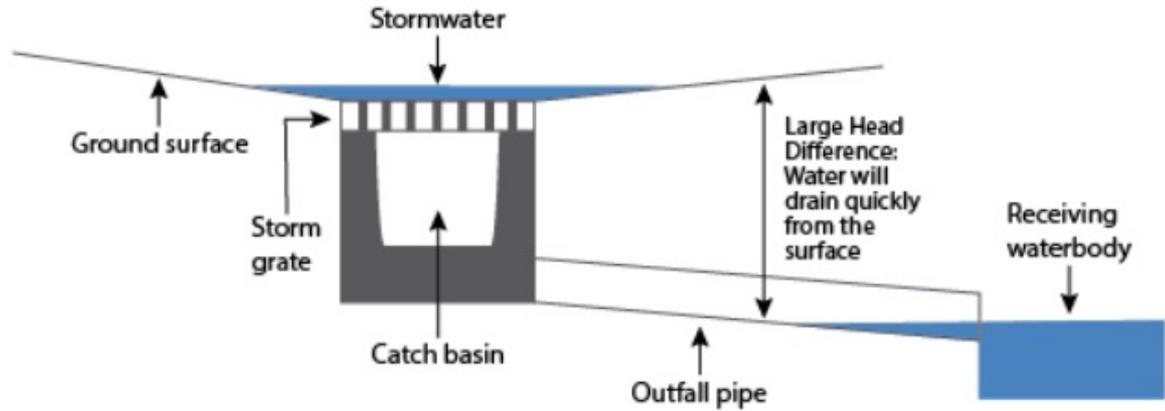
| ● 褒忠 (褒忠鄉) | | | | |
|------------|----|-----|-----|--|
| 時間 | 雨量 | 警戒 | | |
| | | 二級 | 一級 | |
| 1H | 0 | 50 | 60 | |
| 3H | 0 | 110 | 120 | |
| 6H | 0 | 150 | 170 | |

淹水成因 (雙影響因子)

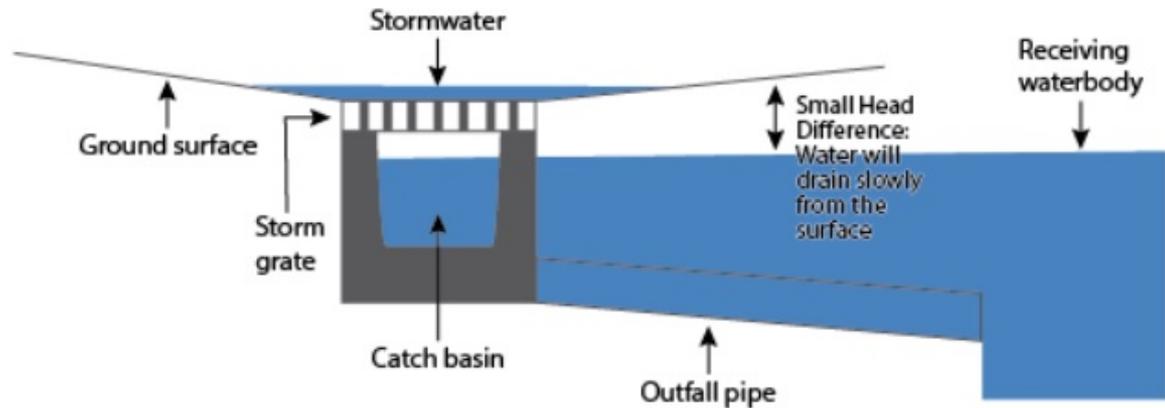
Flooding is caused by heavy rainfall overwhelming drainage capacity



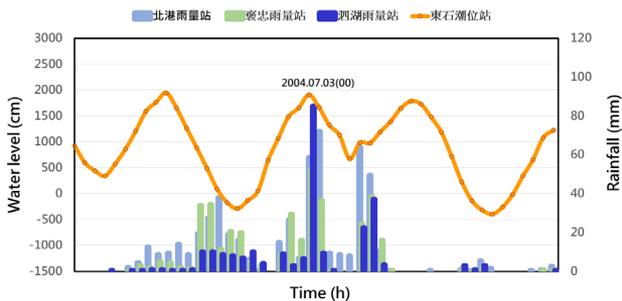
Low Tide Scenario



High Tide Scenario



Typhoon Mindulle (2004)



Copula describes the dependence structure between the variables

- Random variables: X and Y
- Marginal cumulative distribution functions of X and Y: $F_X(x)$ and $F_Y(y)$
- The continuous joint probability distribution function (**Joint CDF**):

$$F_{XY}(x, y) = C(F_X(x), F_Y(y))$$

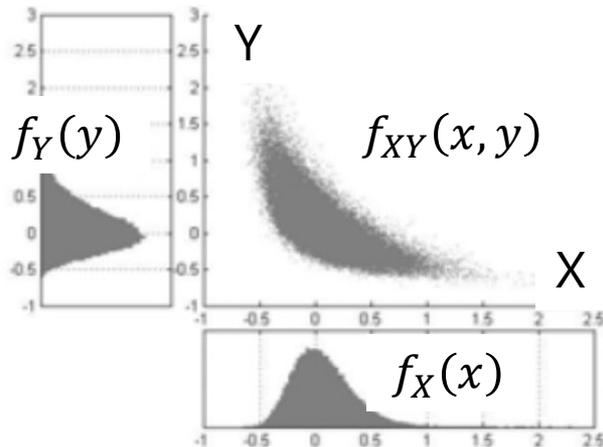
- Joint probability density function (**Joint PDF**)

$$f_{XY}(x, y) = \frac{\partial^2 F_{XY}(x, y)}{\partial x \partial y}$$

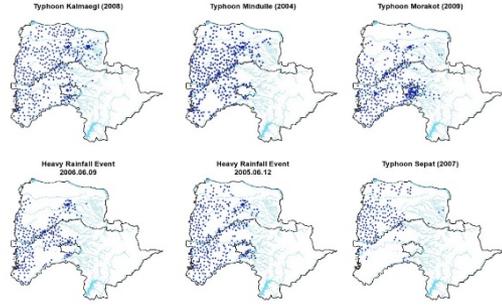
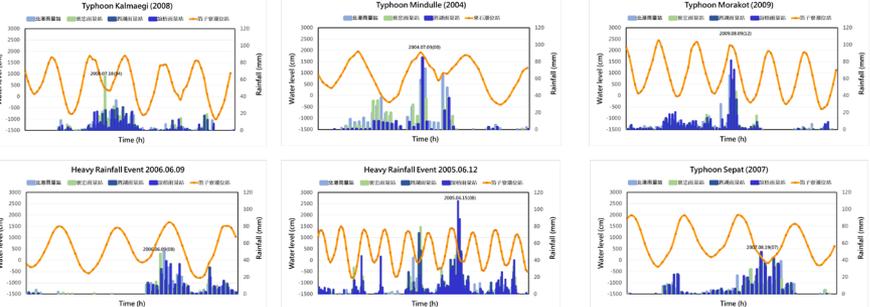
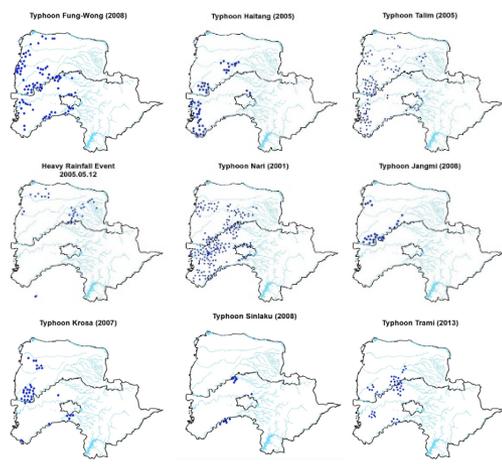
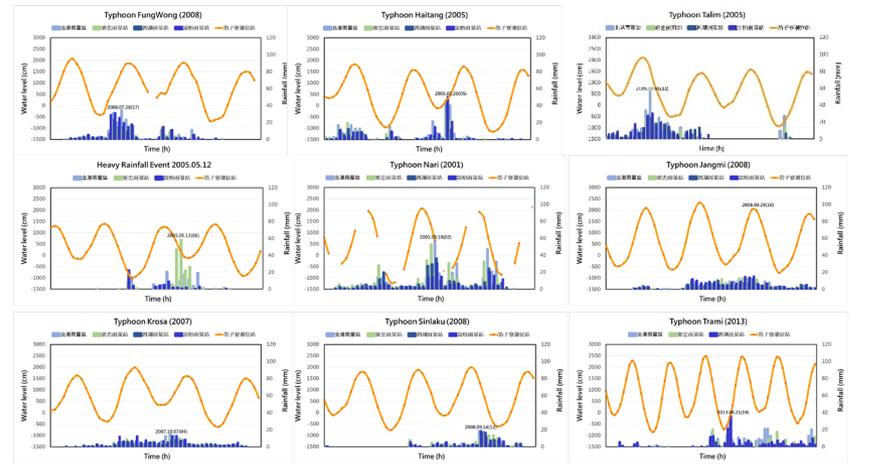
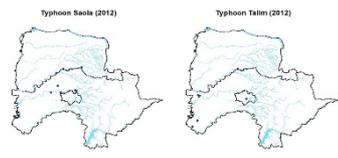
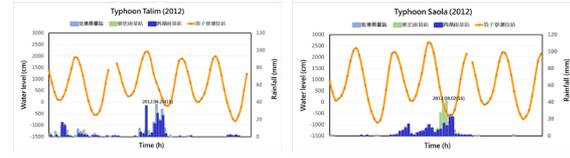
...

$$f_{XY}(x, y) = c(u, v) f_X(x) f_Y(y)$$

where $c(u, v)$ is the copula density function



淹水事件 和 雨量、潮位

| 淹水情境 | 淹水位置 | 雨量&潮位時序圖 |
|---|---|--|
| <p>強降雨 + 大潮</p> |  |  |
| <p>強降雨 + 中水位</p> <p>-----</p> <p>降雨 + 高水位</p> |  |  |
| <p>強降雨 + 低水位</p> |  |  |

資料採樣方式

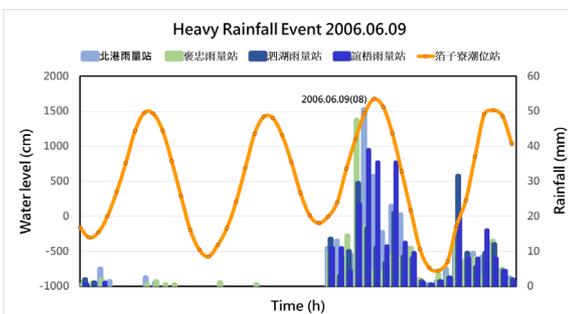
資料位置：雲嘉示範區

採樣資料：時雨量、時潮位

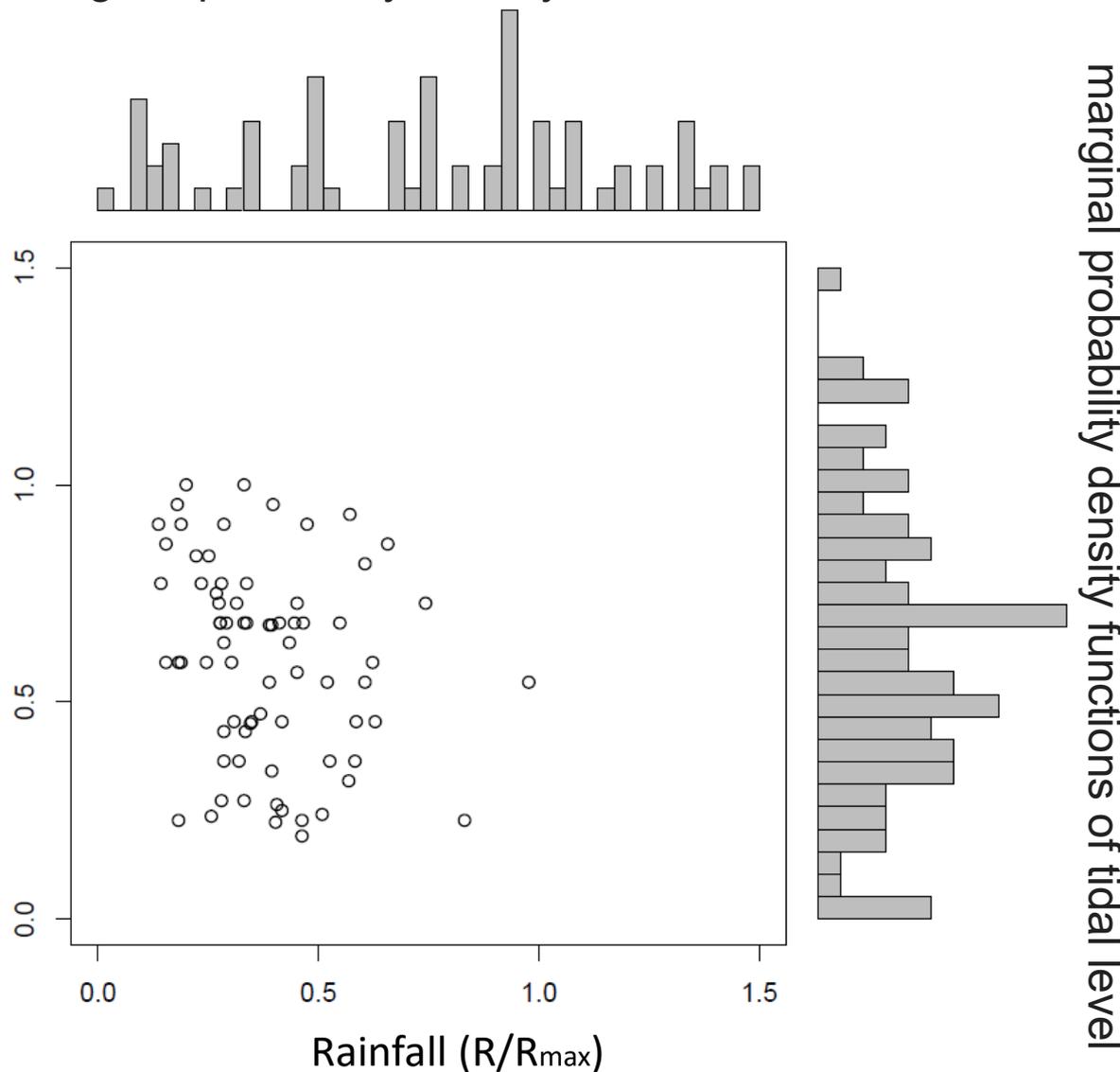
採樣區間：6小時

採樣依據：6小時區間中
有強降雨或大潮

Tidal level
(L/L_{max})

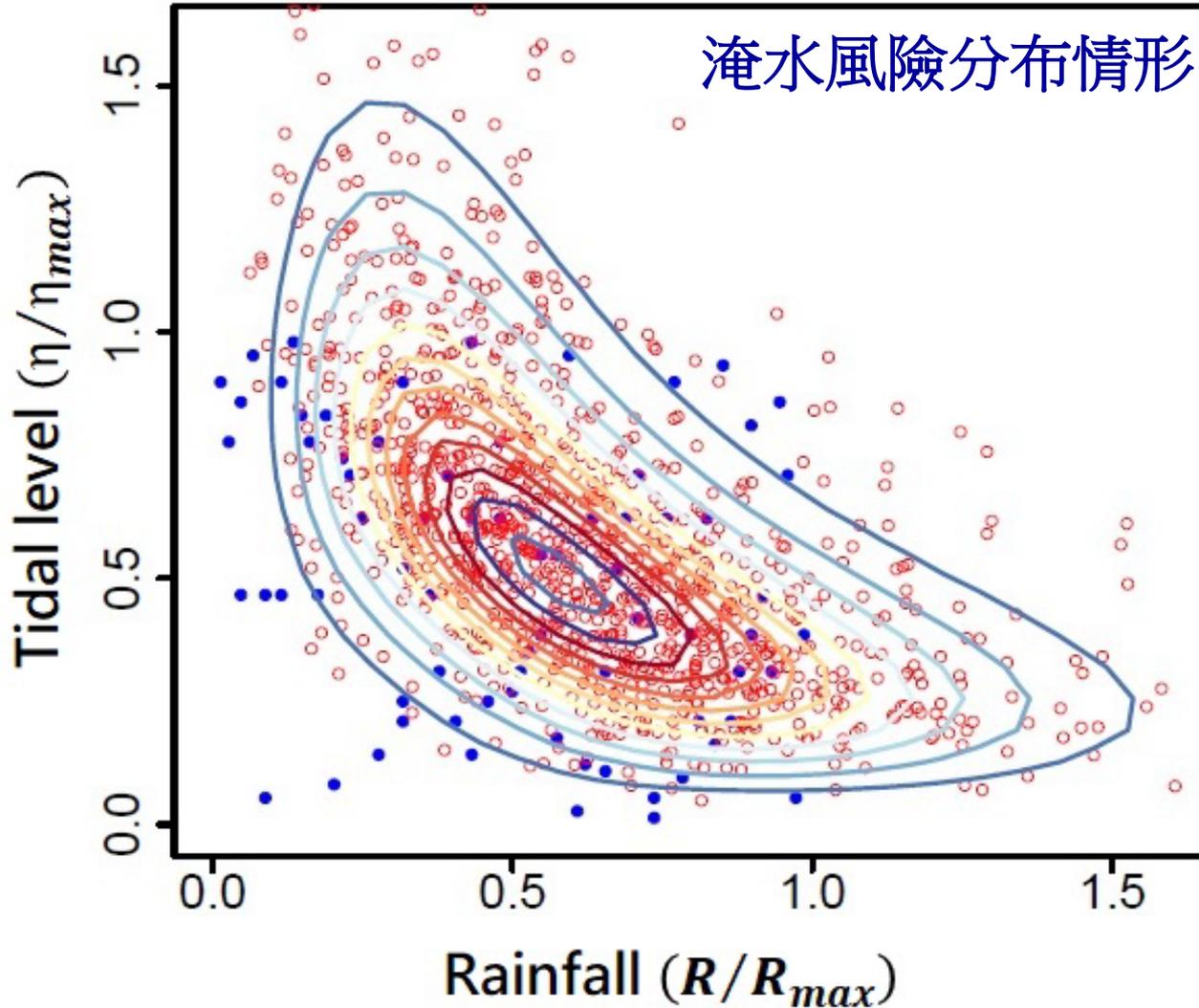


marginal probability density functions of rainfall



marginal probability density functions of tidal level

Observation/Simulation:Blue/Red



最適聯合函數：
Frank Copula

聯合函數參數：
parameter=-4.83

資料相依性：
Kendall's $\tau = -0.44$



敬請指正

Thank you for your time and attention