

# Ecosystem services

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## Calculating ecosystem services

Each species  $i$  can contribute to the existence of a  $j$  ecosystem service. Therefore, we can map the relation species / ecosystem services as follows:

$$E = \mathbf{P}\vec{x}$$

where,  $\mathbf{P}$  is a matrix of  $k \times s$  dimension, in which  $k$  is the ecosystem services vector and  $s$  is the species vector. The vector  $\vec{x}$  is related to the state of species (present, absent, abundance...). Each entry  $P_{ij}$  depicts the effect of one individual species  $j$  on each ecosystem service  $i$ . The  $P_{ij}$  value could be the raw value or the relative value of each species  $i$  contribution to the ecosystem service. For our purpose,

$$E_{ij} = \begin{cases} P_{ij}, & \text{if } x_i = 1 \\ 0, & \text{if } x_i = 0 \end{cases}$$

Therefore, the effects of species loss could be investigated as  $\Delta E = E^{(t_0)} - E^{(t_n)}$ .

## Running an example

```
set.seed(12)
```

```
#P matrix  
#species state
```

```
s <- 10 #n species  
state = rbinom(10, 0:1, prob = 0.5) #species state (0,1)  
k <- 3 #n ecosystem services  
P <- matrix(runif(k*s, 0, 1), nrow = s, ncol = k)  
P
```

```
##           [,1]      [,2]      [,3]  
## [1,] 0.033895622 0.43933432 0.2679436  
## [2,] 0.178785004 0.45760715 0.5047680  
## [3,] 0.641665366 0.54070755 0.1885869  
## [4,] 0.022877743 0.66567983 0.4394293  
## [5,] 0.008324827 0.11269894 0.6698193  
## [6,] 0.392697197 0.21836717 0.2408832
```

```
## [7,] 0.813880559 0.78783635 0.8932649
## [8,] 0.376248455 0.09785304 0.8827564
## [9,] 0.380812184 0.70983047 0.8140633
## [10,] 0.264918378 0.21782304 0.6332646
```

```
#Ecosystem services status
```

```
E <- P*state
E
```

```
##           [,1]      [,2]      [,3]
## [1,] 0.00000000 0.0000000 0.0000000
## [2,] 0.00000000 0.0000000 0.0000000
## [3,] 0.00000000 0.0000000 0.0000000
## [4,] 0.02287774 0.6656798 0.4394293
## [5,] 0.00000000 0.0000000 0.0000000
## [6,] 0.39269720 0.2183672 0.2408832
## [7,] 0.00000000 0.0000000 0.0000000
## [8,] 0.00000000 0.0000000 0.0000000
## [9,] 0.00000000 0.0000000 0.0000000
## [10,] 0.00000000 0.0000000 0.0000000
```

```
#We can see the value of each ecosystem service
```

```
status <- colSums(E)
status
```

```
## [1] 0.4155749 0.8840470 0.6803126
```

```
#Delta E
```

```
(state_t0 = rbinom(10, 0:1, prob = 0.8)) #species state (0,1)
```

```
## [1] 0 0 0 1 0 0 0 1 0 1
```

```
(state_tn = rbinom(10, 0:1, prob = 0.3)) #species state (0,1)
```

```
## [1] 0 0 0 0 0 1 0 0 0 1
```

```
(P0 <- P*state_t0)
```

```
##           [,1]      [,2]      [,3]
## [1,] 0.00000000 0.00000000 0.0000000
## [2,] 0.00000000 0.00000000 0.0000000
## [3,] 0.00000000 0.00000000 0.0000000
## [4,] 0.02287774 0.66567983 0.4394293
## [5,] 0.00000000 0.00000000 0.0000000
## [6,] 0.00000000 0.00000000 0.0000000
## [7,] 0.00000000 0.00000000 0.0000000
## [8,] 0.37624846 0.09785304 0.8827564
## [9,] 0.00000000 0.00000000 0.0000000
## [10,] 0.26491838 0.21782304 0.6332646
```

```
(Pn <- P*state_tn)
```

```
##           [,1]      [,2]      [,3]
## [1,] 0.0000000 0.0000000 0.0000000
## [2,] 0.0000000 0.0000000 0.0000000
## [3,] 0.0000000 0.0000000 0.0000000
## [4,] 0.0000000 0.0000000 0.0000000
## [5,] 0.0000000 0.0000000 0.0000000
## [6,] 0.3926972 0.2183672 0.2408832
## [7,] 0.0000000 0.0000000 0.0000000
## [8,] 0.0000000 0.0000000 0.0000000
## [9,] 0.0000000 0.0000000 0.0000000
## [10,] 0.2649184 0.2178230 0.6332646
```

```
colSums(P0)
```

```
## [1] 0.6640446 0.9813559 1.9554503
```

```
colSums(Pn)
```

```
## [1] 0.6576156 0.4361902 0.8741478
```

```
delta <- P0 - Pn
delta
```

```
##           [,1]      [,2]      [,3]
## [1,] 0.00000000 0.00000000 0.00000000
## [2,] 0.00000000 0.00000000 0.00000000
## [3,] 0.00000000 0.00000000 0.00000000
## [4,] 0.02287774 0.66567983 0.4394293
## [5,] 0.00000000 0.00000000 0.00000000
## [6,] -0.39269720 -0.21836717 -0.2408832
## [7,] 0.00000000 0.00000000 0.00000000
## [8,] 0.37624846 0.09785304 0.8827564
## [9,] 0.00000000 0.00000000 0.00000000
## [10,] 0.00000000 0.00000000 0.00000000
```

```
colSums(delta)
```

```
## [1] 0.006429002 0.545165702 1.081302481
```