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Lampiran

Lampiran 1: Analitik

- > *restart* := with(*linalg*) :
- > $\mu[1] := 1.9 : \mu[2] := 1.5 : K[N1] := 0.15 : K[N2] := 0.6 : K[I1]$
 $:= 30 : K[I2] := 5 : m[p] := 0.145 : g := 1.5 : K[Z] := 1.4 : \beta$
 $:= 0.2 : \varepsilon := 0.06 : \tau := 0.1 : C[0] := 1.2 :$
- > $\alpha[1] := \mu[1] \left(1 - e^{-\frac{1}{K[I1]}} \right) : \alpha[2] := \mu[2] \left(1 - e^{-\frac{1}{K[I2]}} \right) :$
- > $d := C[0] - N - P[1] - P[2] - Z :$
- >
- > $p1 := \tau \cdot (C[0] - N - P[1] - P[2] - Z) - \alpha[1] \cdot \frac{N}{K[N1] + N} \cdot P[1]$
 $- \alpha[2] \cdot \frac{N}{K[N2] + N} \cdot P[2] : p2 := \left(\alpha[1] \cdot \frac{N}{K[N1] + N}$
 $- m[p] \right) \cdot P[1] - g \cdot \left(\frac{P[1]}{K[Z] + P[1] + P[2]} \right) \cdot Z : p3 := \left(\alpha[2]$
 $\cdot \frac{N}{K[N2] + N} - m[p] \right) \cdot P[2] - g \cdot \left(\frac{P[2]}{K[Z] + P[1] + P[2]} \right) \cdot Z :$
 $p4 := \left(g \cdot \beta \cdot \frac{P[1] + P[2]}{K[Z] + P[1] + P[2]} - \varepsilon \right) \cdot Z :$
- > *solusi* := solve({*p1*, *p2*, *p3*, *p4*}, {*N*, *P[1]*, *P[2]*, *Z*}) :
- > *vek1* := vector([*p1*, *p2*, *p3*, *p4*]) :
- > *jcob* := jacobian(*vek1*, [*N*, *P[1]*, *P[2]*, *Z*]) :
- > *job1* := subs(*solusi*[1], evalm(*jcob*)) :
- > *pkar1* := charpoly(*job1*, λ) :
- > *eigenvalues* (*job1*) :
- > *job2* := subs(*solusi*[2], evalm(*jcob*)) :
- > *pkar2* := charpoly(*job2*, λ) :
- > *eigenvalues* (*job2*) :
- > *job3* := subs(*solusi*[3], evalm(*jcob*)) :
- > *pkar3* := charpoly(*job3*, λ) :
- > *eigenvalues* (*job3*) :
- > *job4* := subs(*solusi*[4], evalm(*jcob*)) :
- > *pkar4* := charpoly(*job4*, λ) :
- > *eigenvalues* (*job4*) :
- > *job6* := subs(*solusi*[6], evalm(*jcob*)) :
- > *pkar6* := charpoly(*job6*, λ) :
- > *eigenvalues* (*job6*) :

Lampiran 2: Simulasi Numerik dengan Parameter Tertentu

- > *restart* : *with(linalg)* :
- > $\mu[1] := 1.9$: $\mu[2] := 1.5$: $K[N1] := 0.15$: $K[N2] := 0.6$: $K[I1]$
 $:= 30$: $K[I2] := 5$: $m[p] := 0.145$: $g := 1.5$: $K[Z] := 1.4$: β
 $:= 0.2$: $\varepsilon := 0.06$: $\tau := 0.1$: $C[0] := 1.2$:
- > $\alpha[1] := \mu[1] \left(1 - e^{-\frac{1}{K[I1]}} \right)$: $\alpha[2] := \mu[2] \left(1 - e^{-\frac{1}{K[I2]}} \right)$:
- > $d := C[0] - N - P[1] - P[2] - Z$:
- >
- $p1 := \tau \cdot (C[0] - N - P[1] - P[2] - Z) - \alpha[1] \cdot \frac{N}{K[N1] + N} \cdot P[1]$
 $- \alpha[2] \cdot \frac{N}{K[N2] + N} \cdot P[2]$: $p2 := \left(\alpha[1] \cdot \frac{N}{K[N1] + N} \right.$
 $- m[p] \cdot P[1] - g \cdot \left(\frac{P[1]}{K[Z] + P[1] + P[2]} \right) \cdot Z$: $p3 := \left(\alpha[2] \right.$
 $\cdot \frac{N}{K[N2] + N} - m[p] \cdot P[2] - g \cdot \left(\frac{P[2]}{K[Z] + P[1] + P[2]} \right) \cdot Z$:
- $p4 := \left(g \cdot \beta \cdot \frac{P[1] + P[2]}{K[Z] + P[1] + P[2]} - \varepsilon \right) \cdot Z$:
- > *solusi* := *solve* ({*p1*, *p2*, *p3*, *p4*}, {*N*, *P[1]*, *P[2]*, *Z*}) :
- > *vek1* := *vector* ([*p1*, *p2*, *p3*, *p4*]) :
- > *jcob* := *jacobian* (*vek1*, [*N*, *P[1]*, *P[2]*, *Z*]) :
- > *job1* := *subs* (*solusi*[1], *evalm*(*jcob*)) :
- > *pkar1* := *charpoly* (*job1*, λ) :
- > *eigenvalues* (*job1*) :
- > *job2* := *subs* (*solusi*[2], *evalm*(*jcob*)) :
- > *pkar2* := *charpoly* (*job2*, λ) :
- > *eigenvalues* (*job2*) :
- > *job3* := *subs* (*solusi*[3], *evalm*(*jcob*)) :
- > *pkar3* := *charpoly* (*job3*, λ) :
- > *eigenvalues* (*job3*) :
- > *job4* := *subs* (*solusi*[4], *evalm*(*jcob*)) :
- > *pkar4* := *charpoly* (*job4*, λ) :
- > *eigenvalues* (*job4*) :
- > *job6* := *subs* (*solusi*[6], *evalm*(*jcob*)) :
- > *pkar6* := *charpoly* (*job6*, λ) :
- > *eigenvalues* (*job6*) :
- > *sol* := *solve* ({*p1*, *p2*, *p3*, *p4*}, {*N*, *P[1]*, *P[2]*, *Z*}) :
- > *with* (*plots*) :

$$\begin{aligned}
\text{sys} := & \frac{d}{dt}N(t) = \tau \cdot (C[0] - N(t) - P[1](t) - P[2](t) - Z(t)) - \alpha[1] \\
& \cdot \frac{N(t)}{K[N1] + N(t)} \cdot P[1](t) - \alpha[2] \cdot \frac{N(t)}{K[N2] + N(t)} \cdot P[2](t), \\
\frac{d}{dt}P[1](t) = & \left(\alpha[1] \cdot \frac{N(t)}{K[N1] + N(t)} - m[p] \right) \cdot P[1](t) - g \\
& \cdot \left(\frac{P[1](t)}{K[Z] + P[1](t) + P[2](t)} \right) \cdot Z(t), \frac{d}{dt}P[2](t) = \left(\alpha[2] \right. \\
& \cdot \frac{N(t)}{K[N2] + N(t)} - m[p] \left. \right) \cdot P[2](t) - g \\
& \cdot \left(\frac{P[2](t)}{K[Z] + P[1](t) + P[2](t)} \right) \cdot Z(t), \frac{d}{dt}Z(t) = \left(g \cdot \beta \right. \\
& \cdot \left. \frac{P[1](t) + P[2](t)}{K[Z] + P[1](t) + P[2](t)} - \epsilon \right) \cdot Z(t) :
\end{aligned}$$

- > $fns := \{N(t), P[1](t), P[2](t), Z(t)\} :$
- > $L := dsolve(\{sys, N(0) = 1.1, P[1](0) = 0.01, P[2](0) = 0.01, Z(0) = 0.01\}, fns, type = numeric, method = rkf45) :$
- > $odeplot(L, [[t, N(t), color = RED, thickness = 3]], 0..1000) :$
- > $odeplot(L, [[t, P[1](t), color = blue, thickness = 3]], 0..500) :$
- > $odeplot(L, [[t, P[2](t), color = RED, thickness = 3]], 0..100) :$
- > $odeplot(L, [[t, Z(t), color = blue, thickness = 3]], 0..500) :$